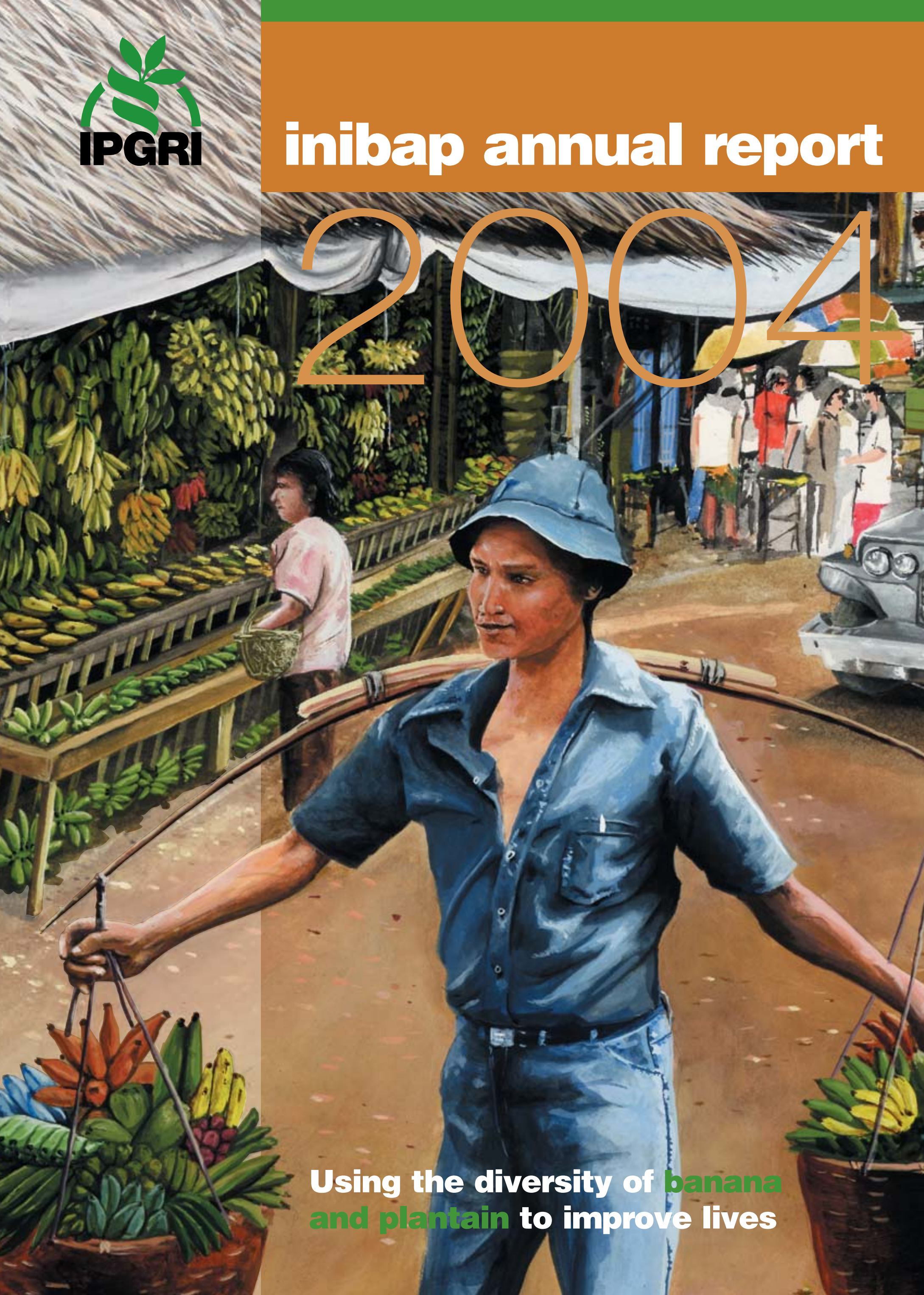
# inibap annual report

# 2004



**Using the diversity of banana and plantain to improve lives**

# Contents

The mission of the **International Network for the Improvement of Banana and Plantain (INIBAP)** is to increase the productivity and stability of banana and plantain grown on smallholdings for domestic consumption and for local and export markets.

INIBAP has four specific objectives:

- to organize and coordinate a global research effort on banana and plantain, aimed at the development, evaluation and dissemination of improved cultivars and at the conservation and use of *Musa* diversity;
- to promote and strengthen regional efforts to address region-specific problems and to assist national programmes within the regions to contribute towards, and benefit from, the global research effort;
- to strengthen the ability of NARS to conduct research on bananas and plantains;
- to coordinate, facilitate and support the production, collection and exchange of information and documentation related to banana and plantain.

INIBAP is a network of the International Plant Genetic Resources Institute (IPGRI).

The **International Plant Genetic Resources Institute (IPGRI)** is an independent international scientific organization that seeks to advance the conservation and use of plant genetic diversity for the well being of present and future generations. It is one of 15 Future Harvest Centres supported by the Consultative Group on International Agricultural Research (CGIAR), an association of public and private members who support efforts to mobilize cutting-edge science to reduce hunger and poverty, improve human nutrition and health, and protect the environment. IPGRI has its headquarters in Maccarese, near Rome, Italy, with offices in more than 20 other countries worldwide. The Institute operates through three programmes: (1) the Plant Genetic Resources Programme, (2) the CGIAR Genetic Resources Support Programme and (3) the International Network for the Improvement of Banana and Plantain (INIBAP).

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# Foreword

This is the second INIBAP Annual Report in our new format – that focuses on sharing our experiences in using the diversity of banana and plantain to improve livelihoods. The response to this new format has been very positive and the separate linguistic versions, in particular, have scored points with our Spanish- and French-speaking partners.

For the 2004 edition, we are covering our long-standing work on using and conserving diversity of bananas on farms in the Great Lakes zone of Uganda and Tanzania, where millions of people are dependent on a unique set of highly diversified varieties that are endemic to the East African highlands. In recent years, pests, diseases and an increased emphasis on marketing, among other factors, have resulted in farmers abandoning some of the less commercial endemic cultivars. A project that is broadening the utilization options for banana varieties and emphasizes their cultural value has helped to reverse this trend and is helping to restore the region's fragile natural resource base at the same time.

From western Africa and Latin America, we are bringing the latest instalment in a technology transfer story that started in 2001 with the visit of a group of West African farmers, extension workers and researchers to see high-density plantain plantations in the Dominican Republic and Costa Rica. As market forces evolve, we expect this intensive production system to come into its own to feed the growing demand from the burgeoning cities of West and Central Africa.

Meanwhile, in Asia, the efficiency of a large-scale private enterprise in producing tissue-culture banana plants is providing the foundation for an effective public-private network, launched by INIBAP, that is rehabilitating production of the traditional Filipino cultivar Lakatan after it had been all but wiped out by a virus epidemic. And, finally, our fourth story recounts the painstaking detective work being done by our partners in trying to understand how and under what circumstances another virus, concealed in the banana genome, comes out of hiding and causes a disease that has seriously disrupted the distribution of improved hybrids.

The year 2004 was also marked by the First International Congress on *Musa*, held in Malaysia from 6 to 9 July. Organized by INIBAP and the Malaysian Agricultural Research and Development Institute (MARDI), the congress brought together some 250 delegates from all over the world, and from disciplines as far apart as genomics and fruit marketing, to share discussions and experiences around the theme of *Harnessing research to improve livelihoods*. The keynote papers and other highlights of the congress were published in the December 2004 issue of INFO*MUSA*.

Our long-standing interest in using the diversity of bananas – and managing the diversity within banana-based systems – to improve livelihoods, ensured that INIBAP was in the mainstream of discussions leading to the formulation of IPGRI's new strategy, *Diversity for well-being*, launched in September 2004. And in the last quarter of the year, INIBAP staff worked closely with their counterparts in COGENT (the coconut genetic resources network) and in IPGRI's major project on cacao genetic resources and genetic improvement, to prepare a report on the Institute's commodity crops research for a Centre Commissioned External Review. These exercises have helped to ensure that people and diversity remain centre-stage when INIBAP begins its twentieth year, 2005, as an integral part of IPGRI's new programme on *improving livelihoods in commodity-based systems*, that brings together within a coherent framework the Institute's work on banana, coconut and cacao. The name of INIBAP, however, lives on within the new programme as a respected 'brand' representing the network's characteristic style of partnership in banana research.

Emile Frison
Director General, IPGRI

Richard Markham
Director, INIBAP

Farmers and researchers are using a subtle blend of traditional knowledge, science and business skills as they work together in the Great Lakes region of Africa to use and thus conserve some of the richest banana diversity in the world.

# Reconciling modernity and tradition to conserve diversity

*In Uganda, women often tend to the banana plants while the men are in charge of selling the fruits.*

*Florence Kizito, one of the participants and most ardent supporter of the IDRC-funded on-farm conservation project.*

“There was a time when every farmer around here knew the names and the appropriate use of each of these bananas”, reflects Mrs Florence Kizito, indicating her neatly-tended and labelled collection of some thirty East African highland banana cultivars, not far from Masaka town in Uganda. Every home worthy of the name had a banana garden and a man’s worth as a farmer and householder was evident to friends and foes alike from the state of that garden – even though it was mainly women who kept the weeds at bay and neatly trimmed off the dead leaves, to keep the garden looking at its best.

“Nowadays, many people only know the price of banana at the Kampala truck stop – and they grow just a few kinds that give them the best return.” Florence lays the blame for the loss of highland banana diversity firmly on an official extension policy based on imported ‘green revolution’ thinking. “Our ancestor must have turned in his grave as he listened to the extension messages”, she says, alluding to Kintu, the legendary founder of the Buganda Kingdom.

Florence grew up knowing bananas as an integral part of her Kiganda culture (*see A banana for every occasion*), as well as the dominant element in her environment. She

## A banana for every occasion

Kintu, the ancestor said to have founded the Buganda Kingdom, reputedly came to the region with a cow and banana suckers, representing the five main types of highland banana: Nakitembe, Musakala, Nakabululu, Nfuuka and Mbidde. Besides having practical uses, such as treating gastro-intestinal ailments or malaria, tradition required that the right banana variety be used to celebrate the birth of twins or to mourn the death of loved ones – with different varieties to be used for the death of a man or of a woman.

Nakitembe, believed to be one of the oldest cultivars in the Great Lakes region of Central Africa, was a woman's cultivar from the moment of birth: immediately after she was born, the placenta had to be buried, with due ceremony, under a plant of that variety. For a boy-child, the cultivar was Nsowe and similarly his after-birth had to be buried below a clump of that banana. When the boy grew up and set out to find a woman to marry, he needed cultivar Mpologoma ('the lion') as part of bride payments. If he began to stray from hearth and home, his young wife might have employed the services of cultivar Enzinga, whose spirally arranged bunches were supposed to ensure that husbands did not wander.

Market forces that encouraged farmers to grow only a few of the most productive banana varieties for the urban market, threatened to cut whole communities adrift from their cultural roots. However, taking a broader perspective on livelihoods has helped farmers to see how they can use banana diversity to build their social capital, as well as enhance their financial and natural resources. By reasserting traditional uses of bananas, at the same time as developing new ones, farmers have been able to reinforce community cohesion and preserve traditional cultivars.

joined the modern world as a teacher, but she returned to the farm by choice, becoming a successful producer of both bananas and dairy products. Now she has turned her teaching skills to effective use, as an enthusiastic advocate of an innovative project – funded by the International Development and Research Centre of Canada (IDRC) and implemented by INIBAP – on preserving banana diversity for both cultural and economic reasons.

The challenge of the project, explains Eldad Karamura, INIBAP's regional coordinator for Eastern and Southern Africa, was to show farmers that there was no inherent conflict between preserving traditional values and achieving success in the contemporary market economy. "The farmers were being offered a stark choice: between increasing their income or preserving their cultural identity," says Eldad, himself a child of the banana culture of Uganda's fertile south-western corner. However, in long and patient consultation with communities involved in the project, in the Kagera region

*Every home worthy of the name had a banana garden and a man's worth as a farmer and householder was evident to friends and foes alike from the state of that garden* of Tanzania and the districts of Masaka and Bushenyi in Uganda, project facilitators explored all possible dimensions of the issue. Eldad again: "The problem of poverty and the need to grow only what the market could take were raised and discussed at all meetings. Were culture and modernization at war? By all means no! Could our traditional cultivars really meet our cultural obligations and our income challenges at the same time? That's the hypothesis the project set out to test."

***Farmers in Uganda have to make do with an ever-diminishing land base.***

> *"The farmers were being offered a stark choice: between increasing their income or preserving their cultural identity"*

## Tailor-made solutions

Exploring together a whole range of social and biophysical aspects of the situation, farmers and researchers discovered that they can enhance both the cultural and economic value of cultivar diversity and, in the process, help to reverse the erosion of the region's fragile natural resource base too. Demographic pressure, especially the challenge of supporting growing families on ever-diminishing plots of land, is an underlying issue throughout the project area. The Great Lakes region in the heart of Africa supports some of the densest rural populations in the continent, with figures of over 500 persons per square kilometre recorded in some areas. Pressure on the natural resource base is correspondingly intense.

Communities chose collectively to focus on different aspects of the problem or on pursuing different kinds of solutions. Benchmark sites, representative of each area, were chosen as test beds for new technologies and

### Do you need a cow to be a successful banana farmer?

As the legend of Kintu applies, the people of south-western Uganda were traditionally both cattle-herders and banana growers. Those who were serious about cattle used to breed long-horned Ankole cattle – and indeed, the look of the cows and the exact form of their horns still seems to be a matter of great pride for the breeders. But as the pressure on land increases, farmers are developing new skills in integrating livestock rearing more closely with banana growing. Instead of herding the cows extensively, to make use of both pasture and crop residues, farmers are keeping cows under 'zero-grazing' regimes: the cow (or, for modest establishments, a goat) is kept in a stall, for at least the greater part of the time, and forage is brought to the animal.

This implies a great deal of work. For a cow to be productive, especially to produce high-value dairy products, it needs both considerable quantities of plant matter but also water. Many farmers, however, are finding that the investment of labour pays off. Some of the greatest gains can be made if a farmer can afford the additional investment in a sloping concrete floor for the cattle pen. Farmers and researchers are finding that the urine collected from the cattle provides greater benefits to soil fertility than the manure. And there is even the suggestion that the urine repels banana weevils too. To make the most of zero-grazing, however, the farmer must also pay attention to the genetics of the cows: crosses between traditional breeds and more productive specialist dairy cattle are needed, in order to maintain disease resistance while repaying the investment of labour with more milk. If there is any sign of strife among members of the Bushenyi farmers association, it is because the demand for dairy cows outstrips the current supply.

***Lack of space has forced farmers to keep cows in stalls and bring them forage, in this case chopped up banana pseudostem.***

approaches that might contribute to the solution of each problem or set of problems identified. The project offered a flexible approach to identifying similarities and differences between the situations of participating communities, learning from them and even capitalising on them through exchanges and training.

In Bushenyi, in southwestern Uganda, declining soil fertility, coupled with banana weevil attack, were singled out for attention. In this mountainous benchmark site, some farmers specialized in testing and demonstrating soil erosion control measures; other farmers focused on preparing manure from crop residues, weeds and domestic animal waste. The effort to integrate livestock was boosted by linking-up with a USAID-funded ECOTRUST project that provided cows, which in turn provided manure to fertilize the fields (see *Do you need a cow to be a successful banana farmer?*).

In Lwengo Masaka, in more gently rolling terrain, nearer to Uganda's capital, Kampala, the key specialization was innovative marketing that addressed the problem of making use of the cultivars with small bunches – typically rejected by the traders. This was approached through the packaging and sale of banana fingers instead of whole bunches. In urban markets this broadened the market to include those people who needed only a few fruit and not an entire bunch.

Across the border in Tanzania, farmers in Ibwera, close to Lake Victoria, identified weevil attack as their overriding problem. Weevils not only decimated their traditional cultivars but also greatly diminished their production of plantain for the street food market in Bukoba town. Meanwhile farmers in Chanika, the most remote of the four project sites, had to address the problem of post-harvest losses. As there were no nearby markets for fresh fruit, they evaluated strategies for ensuring a longer marketable life and higher value for their fruit, including solar drying banana figs and making wine.

***For those farmers who cannot afford a cow, a goat or a sheep will do just as well (below). An East African highland banana of the Musakala type (right).***

## Rediscovering diversity

Underpinning the search for solutions to production and marketing problems, and to some extent running in parallel with it, was the quest to understand and harness the region's rich diversity of banana varieties. Nobody knows exactly how bananas first arrived in Africa nor exactly how many kinds there are. Highland bananas are derived from the *acuminata* bananas of South-East Asia and, like the dessert banana of international trade, they are triploids. However, these bananas have evidently been in East and Central Africa a very long time – long enough for numerous mutations to

> *"The same plant grown under different conditions may show quite different characteristics, and these characteristics may also change over time"*

accumulate and for this region to become what taxonomists describe as a secondary centre of diversity for bananas, encompassing perhaps 10% of the world's known banana cultivars.

As mutations created new cultivars and as useful ones were exchanged between communities, they were given numerous names, some used generally throughout the region, others in just a few communities. The person charged with sorting out this biological and social complexity is Deborah Karamura, perhaps the world's leading expert on highland bananas. "The

*Farmers from Masaka discussing strategies to conserve their unique set of banana cultivars.*

'plasticity' of these cultivars presents us with a special challenge," she explains. "The same plant grown in different places, under different conditions, may show quite different characteristics, and these characteristics may also change over time."
The project has sorted out many of these distinctions by assembling the various cultivars in village 'genebanks' in each of the project communities, where they can be compared growing side by side, by researchers and farmers alike. Local names and detailed characteristics are carefully compared and synonymies are established. When distinctions are still unclear, the molecular biologists at Makerere University in Kampala are called in to analyse the DNA 'fingerprint' of the cultivars, an analysis that also helps to show how the cultivars are related to one another.

In the process of sorting out the taxonomy, various traditional cultivars, feared lost in one community, were rediscovered growing not far away in another. Community members exchanged planting material and information about traditional and contemporary uses for each cultivar, in the process exchanging not only the genetic resources, but also the knowledge that will help to ensure their survival.

## Finding markets for diversity

Since the beginning of the project in 1999, the number of participating farmers has grown from 30 to 40 at each site to 200 to 500, each organized into a community-based producers' association. However, enthusiasm for traditional banana diversity was not enough to sustain the effort over the long term. The associations needed group- and financial-management skills, better links to markets and more options for processing their bananas, and thus adding value to the diversity they had so painstakingly restored.

*Some East African highland banana cultivars are peeled and put in a "banana boat" to make a beer rich in vitamin B.*

During 2004 all the participating community associations have been busy, accessing and learning the different arts and trades that can add value to their diverse banana cultivars and broaden utilization. Handicrafts such as basket-weaving make the most of cultivar diversity because the different colour shades of banana fibre, available in different cultivars, enliven the elaborate patterns and textures of the baskets. The handicraft groups around Masaka, formed by women in the banana-producing communities, have made considerable progress in linking up with the tourist industry in Kampala and other urban centres; souvenir shops are already selling banana fibre-based handicrafts and the women have proven adept at adapting and adopting designs to respond to market opportunities.

The Bisheshe community in Chanika has taken the lead in wine making and has sent trainers to both Masaka and Bushenyi to help develop wine making skills in these communities. In much of Uganda, more recently introduced ‘beer bananas’ are used as the raw material for all juice-based products. In the project area, however, farmers are rediscovering the virtues of their own high-juice highland cultivars – even if other cultivars can be pressed (and fermented!) into service when they are available in abundance. Efforts are now under way to persuade the national bureaux of standards of Uganda and Tanzania to establish the standards that will pave the way for quality control and wider marketing. Speciality paper-making offers another route for turning by-products and local labour into high-value products.

The road ahead is not without its share of potholes, speed-bumps and check-points. One major concern remains the long-term maintenance of soil fertility, as more bananas and by-products are taken away to urban markets, instead of being consumed on site and the residues re-cycled onto the banana plots. Even under traditional management, farmers often brought residues from other crops to boost the fertility of their banana plots. So far, Ugandan farmers are not, in general, re-investing their new profits from bananas in mineral fertilizers to replenish the nutrients lost from the farms. The project’s philosophy, however, is that when farmers are making a reasonable profit from the banana plots, they will have a strong incentive to invest in the future of those plots. And there are some signs that this is already happening. As you travel around the project area, you can often identify the active members of the growers’ association, not just from the new corrugated iron roofs on their houses, but also from the greener, stronger banana plants. Perhaps the tradition of judging the skill of a farmer by the state of his – or her – banana plot is being reasserted. And now, with the new spirit and philosophy of the growers’ association, there is every prospect that the skills necessary to sustain the gains will spread throughout the community.

*The women have proven adept at adapting and adopting designs to respond to market opportunities*

***Women from Masaka use banana fibre to make mats (above) and baskets (right) that are sold in Kampala and other cities.***

The greatest enthusiasts of plantain are found in West and Central Africa and in Latin America, two regions that have different approaches to growing their much loved staple. But as markets in Africa develop, local farmers may start using a technology developed in Latin America.

# When West Africa

*The growing demand for plantain by city dwellers is creating a business opportunity for West African farmers.*

There is nothing like the power of seeing with your own eyes. As coordinator of INIBAP's West and Central Africa network, Ekow Akyeampong had often heard his Latin America counterpart talk about high-density planting. This intensive production system not only does wonders for the yields of plantain, he was told, it also reduces losses to diseases. Coming from a region where yields are stagnating, but not the pests and diseases that are attacking plantains, he wanted to see what the 'hype' was all about.

Thanks to funding form the Technical Center for Agricultural and Rural Cooperation (CTA), he was able to do so in 2001 when INIBAP and the *Musa* Research Network for West and Central Africa (*MUSACO*) organized a visit to high-density

*Growing plantain has become an important industry in Costa Rica.*

plantations in the Dominican Republic and Costa Rica for a group of West African farmers, scientists and extension workers. Having seen the results on the ground, it's now the West Africans' turn to show local farmers at home a way of cultivating plantains that is very different from the one they know.

## Ripe for change?

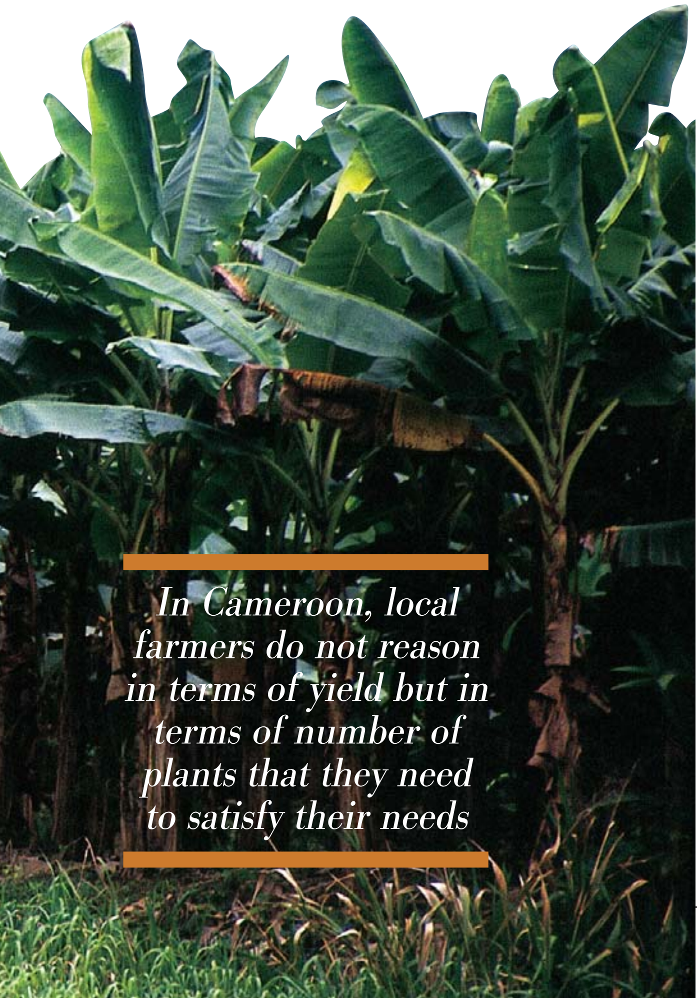
Plantains have been cultivated in West and Central Africa for much longer than in Latin America, where they have been part of the agricultural landscape for less than 400 years. In Cameroon, on the other hand, recent archeological evidence suggests that domesticated *Musa* plants reached the area more than 2500 years ago, or some one thousand years before the generally accepted start of banana farming in the region (see *2002 INIBAP Annual Report*). With time on their side, West and Central African farmers were able to contribute many new cultivars to the diversity of one of their most important staples. When some of these cultivars crossed the Atlantic, they were taken up with the same fervour as in West Africa, where consumption rates generally hover around 100 kg per person per year, with a peak of 200 kg in Gabon. This compares with 160 kg in the coffee-growing areas of Colombia, the birthplace of high-density planting.

The conditions in sub-Saharan Africa are not that different from the ones that prevailed in Colombia when the idea of increasing planting densities first emerged (see *Made in Latin America*). In West and Central Africa, plantain is generally cultivated by smallholders in association with other food crops at very low densities (100 to 800 plants/ha). As a consequence, yields are generally low, between 5 and 10 tonnes per hectare. As Achille Bikoï, a scientist at the *Centre africain de recherches sur bananiers et plantains* (CARBAP) points out in his study of plantain production in Cameroon, local farmers do not reason in terms of yield but in terms of number of plants that they need to satisfy their needs. Since the majority of farmers grow for home consumption, they try to spread their production throughout the year and minimize inputs. The number of plants is meant to ensure an adequate harvest even if the weather doesn't cooperate. Any surplus is sold in local markets.

Farmers, however, have every incentive to change. "The way plantain is currently grown cannot be relied upon to feed the burgeoning populations of Cameroon and other West African countries", explains Akyeampong. Cities, in particular, are growing rapidly. As a result "the demand for plantain in urban areas is high, and so are the prices", continues the INIBAP regional coordinator. "This situation is making plantain cultivation attractive for farmers and those who have the means to acquire the

# meets Latin America

*A high-density plantation in Costa Rica.*



*In Cameroon, local farmers do not reason in terms of yield but in terms of number of plants that they need to satisfy their needs* necessary inputs are very interested in going into commercial plantain production". This is where high-density planting could help. "High-density planting is not one technology but the end product of different technologies", explains Franklin Rosales, the INIBAP regional coordinator for Latin America and the Caribbean. Farmers can adjust three variables: the density of plants (anywhere between 2000 and 6000 plants/ha, although most farmers tend to plant around 2500 and 3000 plants/ha, notes Rosales, since the highest densities require a lot of management); the number of plants per planting hole (one, although anything from two to four is also possible but more demanding); the number of production cycles without replanting (usually one, but not more than three advises Rosales); and the extent to which they want to spread their harvest by planting parts of their field at different times of the year. The only strict requirement is uniform planting material.

***As markets in West Africa develop (left), production systems from Costa Rica (right) will become increasingly relevant.***

If the suckers or plants used are not of uniform size, the taller ones will stunt the development of the smaller ones growing in their shadow. When this happens, the farmer has to act quickly to cut the taller one, which will soon grow back to make a uniform stand. As the many experiments conducted in Latin America have shown, the tallest plants are obtained at the highest planting densities when competition for light is at its maximum. Among the few other parameters that increase with density are the time to harvest and yield. Most of the others (such as number of fingers per bunch, finger diameter and bunch weight) decrease as density increases, but the greater number of bunches in the high-density plots more than compensates for the smaller bunches and the extra weeks of waiting to harvest them (see Table 1). Not negligible either, is the high number of suckers that will be produced, which the farmer can sell to get extra income.

*One of the advantages of high-density planting is that it reduces the incidence of diseases*

***Planting at high densities excludes weed growth.***

**Table 1. Data from experiments conducted in Colombia in the 1980s on the effect of planting density on banana production.**

| Production cycle | Number of fingers per bunch | Finger weight (g) | Bunch weight (kg) | Yield (t/ha) | Harvested plants (%) |
|---|---|---|---|---|---|
| ***1000 plants/ha (5.0m x 2.0m, one plant per planting hole)*** | | | | | |
| First | 46 | 361 | 16.5 | 15 | 91 |
| Second | 53 | 385 | 20.5 | 17 | 84 |
| Third | 58 | 350 | 20.3 | 13 | 62 |
| ***1500 plants/ha (3.3m x 2.0m, one plant per planting hole)*** | | | | | |
| First | 47 | 350 | 16.4 | 22 | 90 |
| Second | 55 | 366 | 20.1 | 19 | 63 |
| Third | 59 | 329 | 19.4 | 18 | 60 |
| ***3000 plants/ha (3.3m x 2.0m, two plants per planting hole)*** | | | | | |
| First | 43 | 362 | 15.7 | 41 | 85 |
| Second | 49 | 305 | 14.8 | 25 | 55 |
| Third | 50 | 284 | 14.1 | 18 | 41 |

## Testing the waters

To see how high-density planting behaves under African conditions, INIBAP funded experiments at the CARBAP station in Nyombe, Cameroon, and at the *Centre national de recherche agronomique* (CNRA) in Azaguié, Côte d'Ivoire. The CARBAP and CNRA scientists respectively planted the cultivar Batard and Orishele in plots of 1666, 2506 and 3333 plants/ha, to test the effect of planting density, and treated as many with fungicides as they left untreated, to test the effect of controlling for black leaf streak disease (BLSD).

One of the advantages of high-density planting is that it reduces the incidence of diseases because the fields are usually replanted after one or two production cycles and the recommendation is to use clean planting material. Moreover, the high densities create a microclimate that hinders the development of the fungus that causes BLSD and by limiting light penetration they also inhibit the production of the photosensitive cercosporin, a product of the fungus involved in leaf necrosis. In Cameroon, however, the experimental plots were too small to generate this microclimate, explains Akyeampong, and as a result the yields observed in the high-density plots (28.7 t/ha) were not as high as the ones obtained in Côte d'Ivoire (more than 38 t/ha). In both cases, weed growth was strongly suppressed in the high-density plots.

*In the late 1970s the cultivation of plantain in Colombia was going through the same growing pains as West Africa is currently experiencing*

## Made in Latin America

In the late 1970s the cultivation of plantain in Colombia was going through the same growing pains as West Africa is currently experiencing. Plantains were mostly grown in association with coffee or cacao, previously unknown diseases were making their appearance, and demand was high while supply was low. The traditional production system needed a technological boost.

At the time, Sylvio Belalcázar, currently an INIBAP Honorary Research Fellow, was working for the *Instituto Colombiano Agropecuario* (ICA), which later became CORPOICA. As head of the plantain programme, he assembled a multi-disciplinary team to breath new life into the culture of plantain. "The demand for food was growing", recalls Belalcázar, "and we had to find a way to increase yield without increasing production costs so as to avoid a rise in the price of plantain." Increasing planting density seemed an obvious place to start, but the various trade offs had to be worked out. The production costs, calculated per kilogram harvested, do indeed go down as density goes up, but researchers needed to know when the law of diminishing returns intervenes.

INIBAP has accompanied the scientific validation of high-density planting in the Latin American and Caribbean region and has greatly contributed to its diffusion through projects, courses, seminars and publications. "Every year we organize between 5 and 10 training courses", says Franklin Rosales of INIBAP. "More than 5000 people have been trained in the last seven years. We've been to all the plantain-producing countries." The practice is especially popular in Cuba where it is being adapted for dessert bananas. One of the most demanding aspects of high-density planting, annual planting, is less of a burden in countries like Cuba where if the farmers don't uproot the plants, hurricanes will.

The INIBAP regional office has also just completed a study in Talamanca, Costa Rica, on the economic aspects of annual and biennial high-density planting (2500 and 3000 plants/ha) in which 10 producers participated. Flooding in the plantations complicated the analysis of the data, but the most profitable option was the annual planting of a density of 2500plants/ha, followed by biennial planting of the same density. Not renewing the plantation saved on the cost of replanting, but other costs, such as the ones related to deleafing and propping, increased during the second production cycle.

INIBAP plans to conduct more tests on high-density planting, in the Democratic Republic of Congo for example, as many things remain to be worked out before high-density planting becomes routine in West and Central Africa. These include requirements in fertilizers and irrigation, choice of varieties, supply of uniform planting material and disease management protocols.

Moreover, when production picks up, these countries will also need better infrastructures to get the plantains to the consumers. But when all is said and done, who will jump on the high-density bandwagon?

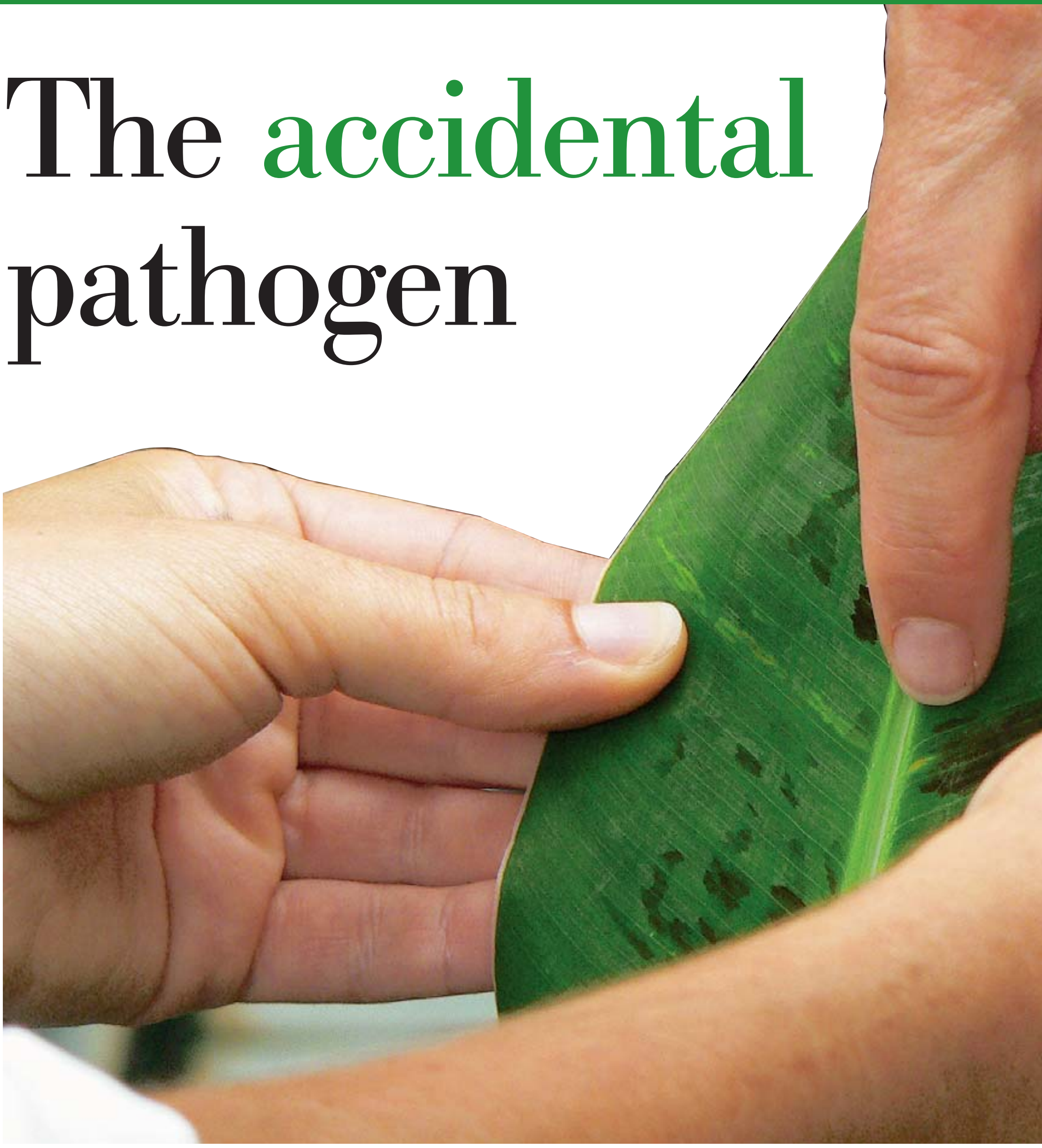
If he were a plantain farmer wanting to switch to high-density planting, Charles Staver, project coordinator at INIBAP in Montpellier, France, reckons he would gear his crop to be ready for harvest when the prices are highest because the supply is low. In places where the prices fluctuate seasonally, this means planting during the dry season, something few farmers do because smallholders generally can't afford irrigation. Of course, if many farmers do the same, they will exert a downward pressure on prices, which is why "you want to be among the early adopters of high-density planting", adds Staver. Another situation in which he would recommend increasing planting density and investing in the management of those more demanding plantations is in the case of a farmer needing to supply regular customers year-round.

The wealth of data INIBAP is accumulating on high-density planting in banana-growing regions (Asia is also experimenting with its own version of high-density production involving annual re-planting) will be used to develop guidelines to help farmers decide whether investing in the practice is worth their while and, if it is, how to tailor it to their situation. ■

***West Africans travelled to Latin America in 2001 to learn about high-density planting.***

How do you outwit a virus that laid down its weapons when it took refuge in the genome of the banana, but has since unexpectedly recovered its power to inflict harm on its host? INIBAP has teamed up with a French agricultural research institute to find out.

# The accidental pathogen



The banana plants Michel Folliot uses in his experiments have been tested more often than an average Olympic athlete, albeit for the presence of *Banana streak virus* (BSV) rather than steroids, and they have always turned up clean. In the greenhouse in the south of France, where the *Centre de coopération internationale en recherche agronomique pour le développement* (CIRAD) keeps the bananas, no plant from the field is allowed in for fear of contamination. So when his plantlets develop banana streak disease, the CIRAD plant physiologist does not look for an outside source of contamination. He knows that DNA from the virus is embedded in the banana's DNA and that the usually silent integrated sequences were coaxed into pumping out viral particles when the plant was put through the process of tissue culture.

***The symptoms of banana streak disease vary a lot with temperature. Most common symptoms (top) and severe symptoms (below).***

Plant pathologists have been aware of banana streak disease for some time but the virus that causes it was only identified in the late 1980s. Like every virus, it invades living cells to replicate itself (see *The simple life*), but because it is transmitted between plants by slow-moving mealybugs, it is fairly easy to control the spread of the disease by uprooting infected plants.

There was not much cause for alarm until Ben Lockhart and his student Tsitsi Ndowora, from the University of Minnesota in the US, announced in 1999 that integrated BSV sequences could trigger an infection. The news took virologists by surprise. There had been reports of integrated viral sequences in tobacco but no evidence that the integration was mediated by the virus itself, in contrast to animal retroviruses, which integrate their DNA into their host's genome by using a virus-encoded integrase. According to conventional wisdom, retroviruses, such as HIV, are hiding in their host's genome to avoid being disabled by the immune system. Since plants lack an immune system and none of the integrated viral sequences found so far in them have been shown to code for a functional integrase, these integration events are said to have occurred by "illegitimate recombination".

*In bananas, integrated BSV sequences are part and parcel of the B genome, which was donated by the wild species* Musa balbisiana

***In the field, BSV is transmitted between plants by mealybugs* (Planococcus citri).**

Illegitimate or not, other integrated viral sequences have been found in a range of crops since 1999 and may be more common than previously thought. However, of the three viral species that have integrated sequences known to produce infectious viral particles – not all integrated sequences are activable since many are incomplete – BSV is the most worrisome one. In petunia, integrated viral sequences only affect the colour of the flowers, with no impact on production, and in tobacco the disease is only expressed when the plants reach six months of age, which they never do since they are harvested at two months.

In bananas, integrated BSV sequences are part and parcel of the B genome, which was donated by the wild species *Musa balbisiana* (which has two copies of the B genome, hence the shorthand BB to designate it) when it crossed with another wild species, *Musa acuminata* (AA), to produce many of today's varieties of bananas. Interestingly, as noted by Frédéric Bakry, a banana breeder at CIRAD in Montpellier, France, the integrated sequences in *Musa balbisiana* and ABB bananas have never been observed to give rise to infections. "The problem only seems to occur when there is one copy of the B genome, as in AAB bananas".

## CIRAD counterattacks

As evidence was mounting that banana[1] varieties containing the B genome harboured integrated viral sequences, some of which were activable, CIRAD declared a moratorium on their distribution. CIRAD's policy is stricter than the one in force at the INIBAP Transit Center (ITC), which hosts the largest collection of bananas in the world in Leuven, Belgium. The ITC only withholds the distribution of accessions testing positive for the presence of viral particles.

[1] Banana is used to denote both dessert and cooking varieties.

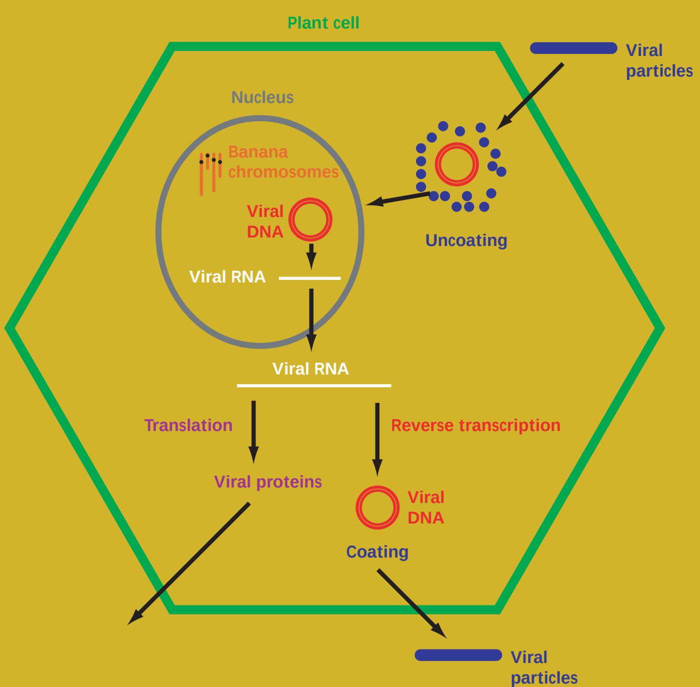
## The simple life

*BSV viral particles isolated from the cultivar Mysore.*

A virus is life at its simplest: a bit of genetic material wrapped in a protein coat. It is unable to do harm, or even reproduce itself, unless it can invade a cell and hijack the cell's machinery to fabricate viral proteins and make copies of itself. BSV is no exception but, unlike most plant viruses, its genome is made of DNA, rather than RNA. BSV belongs to the genus badnavirus and the family caulimoviridae. The virus penetrates the plant cell and proceeds to shed its protein coat. The viral DNA then enters the nucleus where it is transcribed into RNA using enzymes produced by the host. This is followed by reverse transcription, in the cytoplasm, of the viral RNA, which also serves as messenger RNA for producing viral proteins.

BSV is often referred to as a pararetrovirus, but the word has no taxonomic value, according to Andrew Geering, a virologist at Queensland Department of Primary Industries in Australia and a member of the International Committee on Taxonomy of Viruses. "The term pararetrovirus is only used to differentiate these viruses from retroviruses." Even the concept of BSV as a single species is under attack. "What is called BSV is in reality a complex of various viruses", he adds. Geering compared the sequences of four BSV isolates from Australia with other badnaviruses and observed that "the genetic distance between them was so great that it would be incorrect to call them strains." As Geering points out, most badnaviruses are relatively recent discoveries, which perhaps explains why there are few guidelines as to what constitutes a strain and a species.

*Infectious cycle of the BSV.*




*CIRAD researcher extracting RNA.*

*A virus is life at its simplest: a bit of genetic material wrapped in a protein coat*

Plants that test negative in a standard serological test are available for distribution.

"We have different objectives", explains François Côte, head of a CIRAD research unit on banana, plantain and pineapple in Montpellier. "We mass produce banana plantlets for farmers, whereas the ITC is a genebank with a conservation and research mandate." The argument for the moratorium is that introducing to production areas banana plants with activable integrated BSV sequences could change the dynamics of the disease, especially if they have been through tissue culture. Under this scenario, mealybugs would be more likely to encounter infected plants and transmit the disease to clean plants. If there are Cavendish bananas nearby, the economic consequences could be significant since these plants

*Marie-Line Caruana is confident that scientists will learn how to manage activable integrated BSV sequences.*

are very susceptible to the disease. Although most forms of BSV cause relatively little damage to most varieties, researchers are also concerned by the possibility, however remote in practice, that an introduced form of BSV could recombine with others found locally and produce a more damaging disease.

CIRAD also decided to make a pause in its breeding work involving the B genome as hybridization was also shown to increase the probability of triggering the activation of integrated sequences. Bakry has fond memories of the AAB dessert bananas obtained by using *balbisiana* as a parent. What endeared them to the breeder is that they grew like weeds. They were perfect for smallholders who do not have the means to pamper more productive but delicate AAA varieties. Their hardiness and ability to produce roots that penetrate far into the soil came from *balbisiana*, explains Bakry, who is looking forward to the rehabilitation of the B genome.

That will depend in great part on the outcome of the research programme CIRAD has set up to overcome the problem of the activable sequences. Some scientists are trying to understand the activation mechanisms at the genetic and molecular levels, but from a practical point of view it may not be necessary to understand everything about the mechanisms involved to be able to reduce the likelihood that integrated sequences are activated. Hence the strategy developed by CIRAD, and co-funded by the Agropolis platform through INIBAP, to advance on two fronts: understanding the activation mechanisms and evaluating the risk of activating the integrated sequences.

## The search for the genetic trigger

The search for the activation mechanisms started in 1998 with the PhD thesis of Fabrice Lheureux under the supervision of Marie-Line Caruana, a plant virologist at CIRAD in Montpellier. Lheureux worked with the first generation descendants of a cross between a *Musa balbisiana* (BB) and a *Musa acuminata* whose genome had been doubled by using colchicine (AAAA). Both parents had tested negative for the presence of viral particles. Since, under normal circumstances, each parent donates half of its genome to its descendants, this cross ensured that the result of the hybridization would be AAB bananas. About half of the 249 resulting AAB hybrids produced viral particles.

At first, Lheureux looked for differences between the integrated viral sequences in the infected and healthy plants, using a genetic probe made up of BSV sequences isolated from the genome of the cultivar Obino l'ewai. But he could find no differences. Although the hybrids had segregated into two almost equal camps, this was not on the basis of the integrated viral sequences each group carried.

The PhD student set out on a search for AFLP markers anywhere on the banana genome associated with the expression of viral particles. He used enzymes that cut the DNA molecule when they encounter specific genetic sequences, and separated the resulting DNA fragments according to their size by making them move through a gel. This time, Lheureux obtained patterns that were different depending on whether the plant was healthy or infected and thus was able to identify 10 AFLP markers located on the B genome. The analysis of how the markers had segregated pointed to a genetic region that the French virologists called BEL, for BSV expressed locus. The 50:50 segregation observed when BB was crossed with an *acuminata* suggests that only this locus is involved and that the corresponding gene on the homologous chromosome is different.

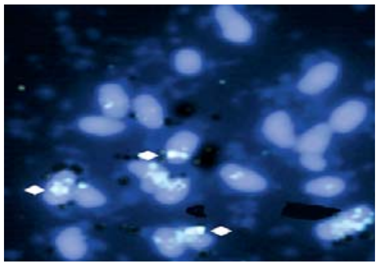
“BEL does not seem to be a viral sequence”, explains Caruana. “It was probably part of the *balbisiana* genome before the virus became integrated. We think the virus was able to integrate its genome into the one of its host because the plant tolerated the virus. Later on the plant became tolerant to the disease; *Musa balbisiana* doesn’t develop the disease when it is inoculated with infected mealybugs. But searching for the BEL factor is like looking for the proverbial needle in a haystack.”

Indeed, the genetic distance separating BEL from its closest genetic marker is huge, 1.2 centiMorgan to be exact. A Morgan is a measure of the relative distance on a chromosome that corresponds to the probability of recombination between the marker and the gene one is looking for. One Morgan is equivalent to a crossover value of 100% and a centiMorgan to 1% crossover value. The probability that the genetic marker would end up close to the BEL factor after a recombination event is so low, the segregating population needed to have a good chance of finding the BEL factor would have to be at least 10 times larger than the one Lheureux used for his work. Since the hybrids the PhD student produced have been destroyed for fear of propagating the virus, starting a new and larger population is not an option.

More recently, scientists from CIRAD, CINVESTAV in Mexico and the Institute of Experimental Botany (IEB) in the Czech Republic started exploring the genome of *Musa balbisiana*. In order to do that, they made copies of its genome and cut it at random. The resulting DNA fragments were inserted in bacteria to be conserved as bacterial artificial chromosomes (BACs) until they are needed – the complete set of BAC clones is called a BAC library.

The scientists screened the *balbisiana* BAC library using as probes the complete sequences of BSV-Ol, BSV-Gf, BSV-Im and BSV-Mys (see *The integrated life*). They found that BSV-Ol

*Searching for the BEL factor is like looking for the proverbial needle in a haystack*



***BSV sequences in B genome chromosomes lighting up after** in situ **fluorescent hybridization**.*

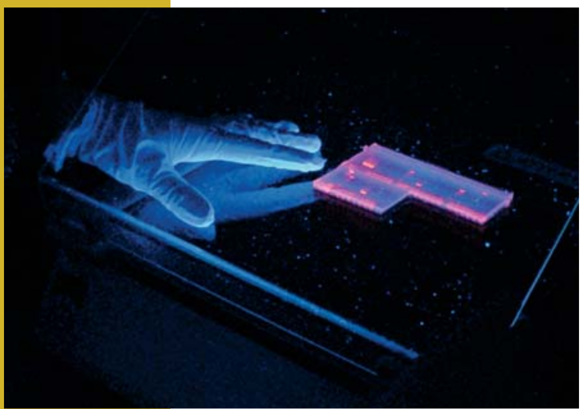
## The integrated life

Four integrated BSV sequences, named after the cultivars they were isolated from, are known: BSV-Ol for Obino l’ewai, BSV-Im for Imove, BSV-Gf for Gold finger and BSV-Mys for Mysore. Of these four, three have been caught escaping the banana genome: BSV-Ol, BSV-Im and BSV-Gf (BSV-Mys is found in *Musa balbisiana* but not in the hybrids).

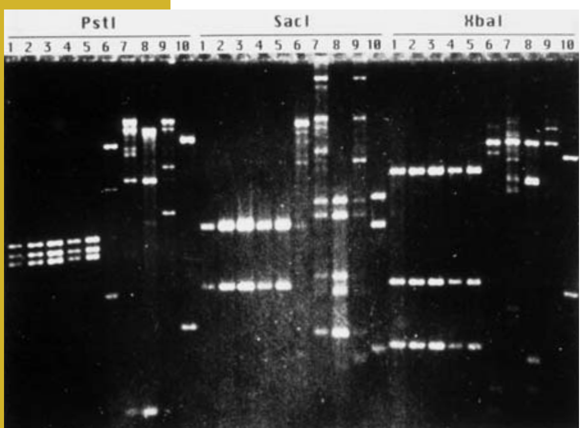
These integrants contain the complete genome of the virus, but not as one uninterrupted sequence. The sequence is interspersed with scrambled fragments of viral DNA, some of which are inverted.

The mysterious part, of course, is what triggers the excision process of these integrated sequences. The current model involves two recombinations (the exchange of material between chromosomes). Are these recombinations, if they occur, spontaneous or aided? Nobody knows how the viral sequences get back together to form an infectious virus and it’s not clear what role the BEL factor plays in the process.

Meanwhile, Andrew Geering in Australia has found evidence that partial BSV sequences are also integrated in *Musa acuminata*. “We don’t know if the integrated sequences in acuminata are activable”, he says. “What we observe is that there is no overlap between the *acuminata* and *balbisiana* sequences, which suggests that integration happened after speciation.” If the presence of BSV sequences integrated in the A genome is confirmed, it will only deepen the mystery of how so many BSV sequences managed to find their way into one, let alone two or maybe more banana genomes.



***Integrated BSV sequences produce distinct ‘fingerprints’ when their DNA is fragmented into pieces that are made to move through a gel**.*




***Gel showing that integrated BSV sequences (lanes 1-5) are very similar to each other compared to field-collected BSV isolates (lanes 6-10).
(Source: Ndowora** et al. **1999. Virology 225:214-220)***

was integrated at, at least, three different sites on the *balbisiana* genome, BSV-Gf at two, BSV-Im at one and BSV-Mys at three sites. They repeated the experiment on two BAC libraries of *Musa acuminata* but came up empty-handed.
They also screened the *balbisiana* BAC library with the three AFLP markers closest to the BEL factor but, while $AFLP_1$ and $AFLP_2$ hybridized with 12 and 13 BAC clones respectively, these were not the same ones. Meanwhile, $AFLP_3$ hybridized with 56 BAC clones – too many to be useful. The genetic release mechanism proving more elusive than anticipated, CIRAD scientists turned their sights on a project conducted with the Indian Institute of Horticultural Research (IIHR).

***Scientists are studying the risk of activating integrating BSV sequences when using horticultural methods of multiplication.***

Gandra Sapraisad from IIHR went to work at CIRAD in Montpellier to look for candidate genes involved in the activation process. He first tested various stress factors (an antibiotic, a polyamine, a demethylating agent and heat shock) on an AAB cultivar, Penkelon noir, but less than 10% of the stressed plants produced viral particles and the expression of the disease was very random with regards to the stress agent.

Sapraisad then used subtractive suppressive hybridization to isolate the genes associated with the activation of the integrated sequences in stressed plants. At any given time, only some of the genes in a cell are active. Activity is detected by the presence of messenger RNA, the intermediary between the gene and the protein it codes for. If you take two identical plants and subject them to the same stress they will both express the genes activated by that stress. But if only one of the plants develops the disease, as a consequence of being stressed, then comparing the genes that are active in each plant, and discarding the ones in common, should point to the genes linked to the activation of the integrated viral sequences. The only problem is that these genes are mixed with the genes involved in the plant's response to the disease, as Franc-Christophe Baurens, the CIRAD scientist who supervised Sapraisad in Montpellier, explains. "These genes are of no interest to us to understand activation, but we are looking for certain types of genes and if we find them we will know more about the activation mechanism."

*Modern multiplication and breeding techniques seem to have woken up the otherwise silent viral sequences that had come to rest in the banana genome*

Meanwhile, Folliot is shuttling back and forth between Montpellier, where he is submitting plantlets of hybrids and AAB cultivars to tissue culture, and Cameroon, where plants that have never been cultured *in vitro* are multiplied at a more leisurely pace using horticultural methods, in close collaboration with the *Centre africain de recherches sur bananiers et plantains* (CARBAP).

Modern multiplication and breeding techniques seem to have woken up the otherwise silent viral sequences that had come to rest in the banana genome. It looks as if it will take a lot of ingenuity and even more sophisticated technology to find a way to lay them to rest again, mainly because of the strong interaction between the elusive BEL and the environment. Caruana, however, is confident: "We can't eliminate the integrated sequences, but we should be able to manage them." She adds that this is not another case of scientists 'playing god', but of scientists tuning the natural machinery.

A partnership between private- and public-sector organizations, brokered by INIBAP, is helping small-scale growers in Luzon return to producing their preferred traditional cultivar, Lakatan, after a devastating disease epidemic.

# Bringing back an old favourite, the capitalist way

***Intensive banana plantations in the south of the Philippines support rehabilitation of smallholder production in the north.***

Most Filipinos reckon that the Cavendish dessert banana, the staple of world trade, is good for only one thing: export to less discerning consumers overseas. They prefer the more complex ‘sweet-acid’ taste (with aromatic overtones) of their own Lakatan variety. However, an outbreak of *banana bunchy top virus* (BBTV) that has been building steadily over the last three decades (see *A stealthy attack*) has effectively put out of production the small producers of the Philippines’ northern island of Luzon, who previously supplied much of the national market. You can still find Lakatan in the busy fruit markets of Manila, the capital, but the price is high and much of the crop is now grown by large-scale producers, some of them multinationals, in plantations on the southerly island of Mindanao. Producing Lakatan

*The key to success seems to lie in assuring a reliable supply of high-quality tissue culture plants at the right price*

for the home market provides a profitable side-line to their principle business of exporting Cavendish bananas to Japan and Korea.

From a technical point of view, there is a relatively straightforward solution to the BBTV problem, based on the use of tissue-culture plantlets that are free of the virus and indeed other pests and diseases. Where the virus pressure is fairly low, growers may be able to get away with uprooting and replacing only the infected plants. However, there are multiple advantages, even for small-scale producers, in going over entirely to replanting regularly with tissue culture plants – if necessary annually – as many of the large plantations have done. There are fewer uncertainties in such a system and farmers have the option of introducing rotations with other crops, such as legumes, that diversify their sources of income and help to restore soil fertility. The rotation can also prove beneficial in managing other key soil-borne pests, such as nematodes.

So why hasn't everyone switched over to using tissue-culture plants? Some farmers may be daunted by the labour involved in clearing and re-planting their entire crop. However, the key to success seems to lie in assuring a reliable supply of high-quality tissue culture plants at the right price. "The government has tried before to supply tissue-culture plants directly to small-scale farmers," recalls Gus Molina, INIBAP's team leader in the Philippines. "But resources were invested in small-scale facilities, run by the public sector, that often did not have the necessary management skills to deliver an adequate product at a viable price." It takes only one bad batch of plants, already infested with the virus or showing 'somaclonal variation' – mutations that often occur after plants have been maintained for too many cycles in tissue culture – to undermine the confidence of farmers in this technology and deter them from investing in it.

*Trainings on management of tissue culture plantlets organized at the Mindoro State university (left) and Pampanga Agricultural College (below) and in Quezon (right).*

*The favorite Lakatan bananas are becoming hard to grow in the face of disease pressure.*

## A second chance

INIBAP is revisiting the problem, bringing in private partners. With the support of the national government, through the Philippines Council of Agricultural Resources Research and Development (PCARRD) and the Department of Agriculture-Bureau of Agricultural Research (DA-BAR), INIBAP has teamed up with one of the largest national producers of bananas, Lapanday Foods, based near Davao in the southern island of Mindanao, to provide the springboard for a major new effort to help the smallholder producers of Luzon. Why should it be different this time? Lapanday has large-scale tissue-culture facilities, producing some 3 million Cavendish plantlets each year to support its own export plantations. These provide the technical base and economies of scale that allow Lapanday to supply high-quality plants of other varieties at a price that even small-scale farmers can afford. Lapanday assures quality by keeping its stock cultures of mother plants free of viruses and other diseases. Plants are 'indexed' to ensure they are virus free each time a new batch is initiated in tissue culture and a short cycle in culture ensures that the plantlets are free of deleterious mutations that otherwise might accumulate.

Lapanday initially helped INIBAP to develop and evaluate the new production system by multiplying traditional varieties and new hybrids, as one of a number of humanitarian initiatives that the company undertakes. “Yes, we embarked on this initially as just another way of trying to help local communities,” explains Emily Fabregar, Research and Development Manager of the subsidiary Lapanday Agricultural and Development Corporation that supplies the plantlets. “We had some spare capacity in our production facilities and this seemed a useful way to keep them busy.” However, this side-line is showing signs of growing into a viable business. Last year, Lapanday produced some 800 000 plantlets of several traditional cultivars and a few new hybrids, mostly to growers in the northern part of the country. “So far, this is not a real money-spinner for us,” continues Fabregar “but we are now covering our costs and that’s a good start on the way to profitability!” The supply of other cultivars can be fitted into ‘dips’ in the Cavendish production and the plantlets go to growers who do not compete directly with Lapanday’s export banana business – which also makes sense from the perspective of business strategy.

Good quality plantlets are, however, only the first part of the story. Tissue culture plantlets are too small and tender to go straight into the field. They must be carefully grown on, under light shade and with ample water, to produce robust planting material. This is where other pilot projects have sometimes foundered: individual farmers may not be able to cope with large numbers of plantlets, in need of intensive care. Yet, if specialist nurseries take on the task of hardening and distributing the plants, costs can quickly get out of hand. In a pilot version of the scheme, mentioned in last year’s Annual Report, INIBAP and national scientists trained

*Emily Fabregar of Lapanday, the private company that produces plantlets for small-scale farmers.*

*The plantlets are hardened off in nurseries (Quirino State College nursery, above) before being planted by farmers (right).*

*Tissue culture plantlets are too small and tender to go straight into the field*

## A network of partners to reach farmers

some farmers to carry out the hardening off as a small business. They purchase the plants at the equivalent of 0.10 US$ and plant them in specially prepared compost (often based on coir dust, a by-product of the Philippines coconut industry), in plastic bags. They grow them for six weeks in plastic bags under shade netting and sell the robust, ready-to-plant bananas to other farmers at a price of about 0.30 US$. That is a manageable price for most growers but provides the nursery owners with an adequate margin.

Of course, what is 'manageable' depends a good deal on the circumstances and perceptions of the individual farmer. For some, micro-credit enterprises can play an important role in helping to make tissue-culture plantlets a viable proposition. In Quirino province, for instance, one of the farmers working with the project, Mercurio 'Mokong' Antimano, participated in the Young Farmers Program of the micro-credit enterprise Quedancor. The scheme includes a credit of PhP300 000 (1 US$=56 Philippines peso) of which 60% comes as a loan, 25% as a grant and 15% as equity. In addition, Mokong received 100 tissue-culture plantlets of Lakatan, Bungulan, Cavendish, FHIA-23, FHIA-25 and Grande naine from Quirino State University in September 2003. On the basis of his early success, Mokong intends to use his grant money to expand his planting by two-and-a-half hectares. Asked which he would rather use, tissue-culture plantlets or suckers, Mokong confidently answers: "tissue-culture plantlets, due to uniformity and more income."

*Simeon Crucido of Cavite State University (left) and Gus Molina of INIBAP examine banana plants ready for distribution to farmers.*

## Enlarging the partnership

Having proved the basic viability of the system, INIBAP, PCARRD and DA-BAR are now teaming up with various public-sector partners to help move the project on to the next level. Lapanday has a minimum order of 2000 plantlets – enough for about one hectare of plantation. These can be sent by air freight and courier service to any part of the Philippines that has an air service. Few individual farmers in Luzon can envisage ordering and planting so many plants at once, so a strategically chosen set of regional universities are currently acting as intermediaries, consolidating orders from many farmers and training some of them, as INIBAP has done previously, to set up nurseries and harden off the plants.

Cavite State University is one such institution that has taken up the challenge. Building on a sound reputation in coffee research and development, the staff at Cavite has taken up the project with enthusiasm. "This is the kind of work, bringing research and the results of research to local communities, at which we excel and which we really enjoy" enthuses Simeon Crucido, Vice-President for Research and leader of Cavite's banana research team.

Along with the familiar Lakatan, farmers are testing new dessert and cooking bananas that are emerging with good report cards from INIBAP's International *Musa* Testing Programme. Some farmers are certainly finding that the new production system and new varieties meets their needs. Domingo 'Domeng' Mojica, a banana farmer in Banaba Cerca, is one of the groups working with Cavite State University. He initially obtained 100 tissue-culture plantlets of Lakatan, Bungulan, FHIA-03 and FHIA-23 and started planting in

## A stealthy attack

"It's hard to pinpoint the start of the banana bunchy top epidemic," according to INIBAP's coordinator for Asia and the Pacific, Dr Gus Molina – a pathologist and Filipino banana enthusiast. "The disease has been here since at least the 1950s and 1960s but it has spread rather slowly and unevenly. In a way the severity of the situation has crept up on us and many small-scale producers were put out of business or switched to other crops before we were able to help them find ways to get on top of the disease".

The virus is spread by the banana aphid, *Pentalonia nigronervosa*. Their infestation of the crop is much less obvious than that of many other aphids because their relatively small colonies mostly remain hidden within the overlapping leaf bases that form the 'trunk' of a banana plant. The aphid causes little obvious damage by its feeding and the first symptoms of the virus it has transmitted may be obvious only during the plant's next growing cycle when the sucker, intended to replace the 'mother plant', instead emerges severely stunted. Large-scale plantation growers are highly disciplined about uprooting such infected plants at the first sign of disease and so keep ahead of the disease. No further fruit can be expected from the virus-infected plants but smallholders, perhaps not understanding the nature of the disease or the urgency of the threat it poses, may well leave the plant to become a source of infection for the rest of the farm. "By the time they have realized how bad the problem is and obtained a proper diagnosis of the disease from an extension agent, it's probably too late to save the crop", explains Molina. "Many farmers do not have the resources, the reserves, to recover from a wipe-out like that."

As so often with pest and disease problems, especially those involving vector-borne diseases whose stealthy spread may be poorly understood by farmers, the path to a solution begins with farmer education. Once farmers understand the ecology of pest and disease problems, they are better able to make informed decisions on counter-measures, including any decisions on investment to be made in new technologies such as tissue-culture plants.

Meanwhile, researchers have their own work cut out, to add to our understanding of the disease. For instance, they need to discover whether any of the numerous alternative host plants for the aphid vectors are, in practice, important to the epidemiology of the disease and whether other crops or wild species can serve as reservoirs for the virus. At the moment researchers are not even sure whether other banana cultivars such as Saba – a cooking banana, also popular in the Philippines – that do not show virus symptoms may actually be harbouring the disease.

October 2003. By his own admission, he was very sceptical at first: how could these tiny plants ever give him a vigorous plant with a big bunch? But with the new plants and advice from INIBAP and Cavite State, Domeng was able to maintain his farm disease free and turn a profit. His mother plants produced heavy bunches and he is currently able to sell his bananas at PhP250-300/bunch. "I earn enough income from bananas which now go to my savings," he muses. For the next planting season, Domeng has orders pending for more tissue-culture plantlets. It's too early to say whether Lakatan

*The new varieties offer the possibility of diversifying farmers' production and so spreading their risks*

production is taking hold again in Luzon but in the meantime the new varieties offer the possibility of diversifying farmers' production and so spreading their risks.

In the next stage of scaling up, the universities expect to hand over their brokering role too to the private sector and so launch a viable new industry.

The universities or other public-sector bodies will probably continue to be partners in the sense of providing technical back-up, perhaps quality control for the plantlets, and watching out for any future threats to the system. The Philippines government has enough confidence in the future of this initiative to have taken over the support of the present development phase from INIBAP's international donors and there is already talk of building up to a nation-wide project.

Meanwhile, INIBAP is continuing to work with some of the research partners to put in place the next steps and other options for a viable, resilient production system. Among the questions still being investigated are the length of time that a farmer can expect to go before needing to replant with fresh tissue-culture bananas and the best crops to use as rotations with banana to prevent the build-up of nematodes. Molina expects annual re-planting to be necessary only in the areas subject to the heaviest BBTV pressure – and research is being conducted, for instance on the epidemiology of the virus, to try to understand what it is about these areas that favours the virus.

Among the lessons that INIBAP is learning through this project is how to work with diverse public- and private-sector partners to solve practical problems within the constrains of an economically competitive industry. And, as the technical problems are resolved in the Philippines, INIBAP is working through its BAPNET regional networks to identify new partners with whom to sow the seeds of the same success in other countries.■

# INIBAP in brief

INIBAP's agenda is divided into four thematic areas:

- Conserving and managing diversity
- Using diversity for genetic improvement
- Supporting regional research and development
- Sharing information.

Progress in each area is summarised together with the activities of the thematic and regional networks for which INIBAP provides the secretariat.

## Conserving and managing diversity

Activities in the conservation and management of banana genetic diversity are centred on the state-of-the-art International *Musa* Germplasm Collection managed by INIBAP at the ITC[1] in KULeuven with the support of the Directorate General for Development Cooperation of Belgium. Most of the collection is held 'in trust, under the auspices of the FAO for the benefit of the international community and is made publicly available through a standard material transfer agreement. A major upgrade of the collection, funded by the World Bank and Gatsby Charitable Foundation, is underway to rejuvenate and validate the taxonomy of the *in vitro* collection and place the entire collection in safe, long-term storage in liquid nitrogen (cryopreservation). Advances in germplasm conservation, and cryopreservation in particular, have helped place INIBAP and KULeuven in a position where they can provide expertise or capacity building to other genebanks. Other activities include the management of data on *Musa* accessions worldwide, research into viral diseases and the molecular and morphological characterization of the accessions.

### Collecting

- In January, Prof. Edmond De Langhe conducted a consultancy mission to the Democratic Republic of Congo to plan the collecting of plantain cultivars in the eastern Congo basin.
- Preparations were made by partners at the University of Kisangani to house the cultivars that will be collected in 2005. The collection will be expanded to include plantains from the Congo basin that are not found in the field collections held at CARBAP and IITA, especially dwarf, semi-dwarf, early fruiting and drought resistant cultivars.
- A workplan for maintaining the field collection has been developed and the areas for conducting collections identified.

### Conservation

- There are currently 1177 accessions being maintained under slow growth conditions in the genebank (of which 986 are held 'in trust).
- Seven accessions received from Oman in 2003 were officially transferred to the ITC collection in 2004.
- In the course of 2004, 1245 samples were removed from MTS for annual subculturing. The cultures were checked for fungal contamination and viability and only the suitable ones were used to establish a fresh set of 20 proliferating shoot cultures.
- The work on rejuvenating the collection, started in 2001, continued. This involves regenerating samples of each accession, growing the plants in greenhouses and then decapitating them to supply suckers, from which new cultures are established. In 2004, 106 accessions, including 89 accessions that were planted for the first time and 17 accessions that needed replanting because the plants had died after planting or after decapitation, were transferred to greenhouses where the vigour and morphology of the plants

[1] See page 44 for the full name of acronyms and abbreviations.

are checked every two months. During the same period, 224 accessions were returned to MTS.

- In 2004, 358 accessions were sent to field sites in Cameroon (173), Guadeloupe (43), Honduras (46), the Philippines (69) and Uganda (27) to evaluate their trueness-to-type.
- Universiti Putra Malaysia began to implement an agreement to cryopreserve zygotic embryos from wild banana species, beginning with testing of the cryopreservation protocol.
- KULeuven continued to work with Infruitech-Nitvoorbij in South Africa and CIBE-ESPOL in Ecuador to cryopreserve the collection. As of the end of 2004, 306 banana accessions had been cryopreserved at KULeuven, 4 at Infruitech and 10 at ESPOL. The arrival at ESPOL of plant material from the ITC was delayed by formalities, while progress at Infruitech was hindered by bacterial contamination.
- Research into the cryopreservation protocol for proliferating meristems using the simple freezing method showed that for the cultivars Cacambou, Grande naine and Williams, the rate of shoot regeneration increased after the application of 0.1 to 0.5 mM cholesterol, sitosterol or stigmasterol to the sucrose preculture medium. The post-thaw regeneration frequencies using the vitrification method were not affected by the addition of sterols.
- In general, the addition of 1 mM of polyamines and aromatic amines to the preculture or regeneration medium did not affect post-thaw shoot regeneration of banana meristems. The addition of tyramine to the preculture medium enhanced the post-thaw shoot regeneration rate of Cacambou and Williams using the simple freezing method.
- A technician has been recruited by KULeuven and trained in cryopreservation to start work on a duplicate 'black box collection' that will be held elsewhere and serve as insurance against the physical loss of the collection in Leuven.
- The management of the collection has been made easier with the installation of a data management system that records most aspects of accession information, from virus indexing results to stock levels. The information is accessed from a hand-held unit that reads the barcodes attached to each accession. All the accessions have been bar-coded and the data for these accessions are now routinely entered in the database by means of this device. Improvements are being made to the system, which will also facilitate the exchange of information with MGIS.
- In response to demands for DNA, the ITC has developed a freeze drying protocol and established a collection of lyophilized leaf samples, which means that even virus-infected accessions can be made available for molecular study. In 2004, 465 samples of 63 rejuvenated accessions have been lyophilized. Each sample consists of ±1g of fresh leaf tissue (or 0.1g of lyophilized tissue) and is kept in an air- and water-tight plastic bag that is stored in a freezer at -20°C. The leaf samples will be made available in 2005.

### Characterization

- The Laboratory of Molecular Cytogenetics and Cytometry at the IEB finished determining the ploidy level of the 1150 accessions held at the ITC at the end of the project. Flow cytometry was used. The method measures the content of nuclear DNA, which is directly proportional to the number of chromosomes. The analysis corroborated the ploidy of 958 accessions and revealed the level of 81 accessions for which it was unknown (Figure 1). The ploidy turned out to be different from the previously accepted level in 88 accessions.
- The characterization activities funded by the Generation Challenge Programme (for "unlocking genetic diversity in crops for the resource-poor") are presented in the section on the Global *Musa* Genomics Consortium on page 29.
- As part of an IFRA-funded project, the genetic diversity in 15 populations of *Musa balbisiana* from China was studied using AFLP. High levels of genetic diversity were revealed. The application of AFLP to 281 plants generated 199 bands.
- In another IFRA-funded project, microsatellites have been used to differentiate ten FHIA hybrids in order to facilitate their identification and the conservation of true types of these varieties. Ten microsatellites were enough to discriminate between FHIA-01 and FHIA-18 but not the other hybrids.

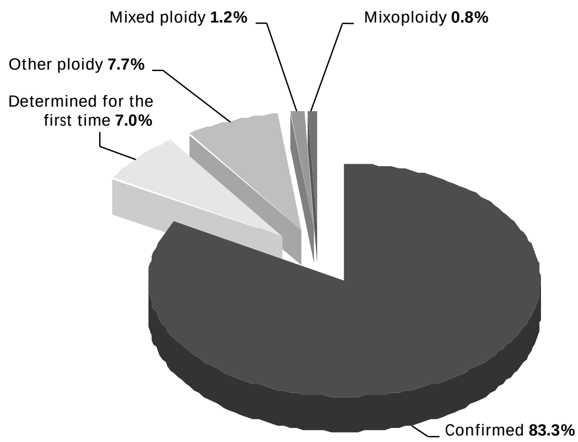



***Figure 1. Distribution of 1150* Musa *accessions in relation to their ploidy level before and after flow cytometry analysis. Mixoploidy refers to a plant containing cells of different ploidy (e.g. 2x and 3x). Mixed ploidy refers to accessions represented by plants of different ploidy.***

### Dissemination

- In 2004, a total of 919 accessions, represented by 3425 tissue culture samples, were sent by the ITC to 32 countries, a 33% increase over 2003. The increase is mainly due to the start, in 2004, of the field verification activity as part of the rejuvenation of the collection.
- The majority of samples (64%) were sent as rooted plantlets.
- In 2004, eight accessions were supplied to the QDPI Virus Indexing Centre in Australia and nine

to the CIRAD one in France. No indexing results were released this year. The proportion of virus-free plants and virus-infected ones is presented in Figure 2.

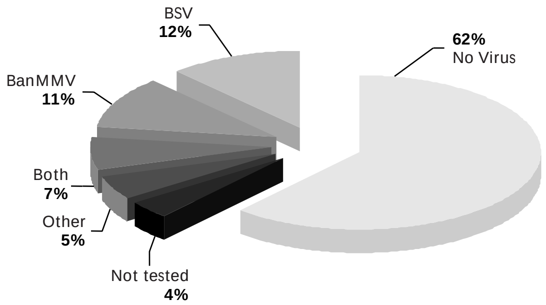



***Figure 2. Virus health status of the banana germplasm collection.***

**Virus research**

- As part of a World Bank-funded project, the *Faculté des Sciences Agronomiques* of Gembloux has shown that a protocol based on thermotherapy combined with meristem isolation to be the most efficient method to eliminate the BanMM virus, which infects 18% of the collection. Routine eradication of the BanMM virus started in 2004. Of the 100 or so accessions needing treatment, 5 rooted plants of each of the first 20 accessions have been sent to Gembloux.
- Plantlets that test virus-negative after therapy are returned to the ITC, where a new set of proliferating cultures is established from a clean plant and five rooted plants are prepared for full virus indexing at one of the Virus Indexing Centres. The entire process will take about one-and-a-half years.
- PPRI has developed a triple antibody sandwich (TAS) ELISA test capable of detecting a wide range of BSV isolates.
- Work was initiated on a survey of molecular diversity of BSV in Colombia, Ecuador, Costa Rica and Mexico to provide data for risk assessment. Thirty samples have been sent from Colombia to CINVESTAV in Mexico to be tested.
- CIRAD scientists are assessing the risk of activating integrated BSV sequences in plants subjected to tissue culture. This work needs to be pursued in parallel with monitoring the virological status in the field of plants that have been indexed as BSV(-) and testing the impact on activation of multiplication techniques such as PIF. (For more information, see the article "*The accidental pathogen*" on page 14.)

**MGIS**

- A total of 5174 accessions from 17 institutions are included in the MGIS database.
- The MGIS database is now linked to the SINGER database – the CGIAR System-wide Information Network for Genetic Resources**.**
- As part of the upgrading of the MGIS database, it is being linked with the ITC genebank management system.

# Using diversity for genetic improvement

INIBAPs support to crop improvement focuses on broadening the genetic base of materials available to banana and plantain breeders around the world, facilitating interactions between breeders, encouraging interactions with specialists in pests and diseases, and helping breeders to achieve the widest possible evaluation and uptake of the improved materials resulting from their work. Much of this agenda is pursued through networks and consortia for which INIBAP provides the secretariat (see below). The PRO*MUSA* network and its specialist working groups seek to bring together and provide support for the worlds very few *Musa* breeding programmes. Meanwhile, molecular techniques are becoming increasingly important in understanding the diversity in the *Musa* genome, how it functions, and how it can be used in crop improvement. The Global *Musa* Genomics Consortium, itself an offshoot of PRO*MUSA*, seeks to achieve synergies by bringing together researchers working at the molecular level. The Generation Challenge Programme has provided an impetus to research in this area and the Consortium has already played a key role in bringing together research groups working on *Musa* to develop a coherent response to this new opportunity.

**Evaluating new varieties**

Through the International *Musa* Testing Programme (IMTP), INIBAP facilitates the testing of new, improved banana varieties in locations around the world. A decade after it was launched, IMTP is in its third and most ambitious phase yet. Thirty-five varieties, including promising improved varieties from all six major banana breeding programmes, have been disseminated to, and are being evaluated by, 50 partners in 25 countries in phase III of IMTP. For the first time, two private companies in Asia have participated in the trials. Countries where test sites are located are Australia, Bangladesh, Burundi, Cameroon, China, Colombia, Costa Rica, Côte d'Ivoire, Dominican Republic, Ethiopia, Haiti, Honduras, India, Indonesia, Malaysia, Mexico, Nicaragua, Peru, Philippines, Rwanda, South Africa, Sri Lanka, Uganda, Venezuela, Vietnam.

- All the trials are now planted and all partners have started evaluating performance. A complete set of data from five institutions has already been received for analysis and integrated into a centralized database.
- The trials at Lapanday and Dole in the Philippines, as well as the trials in Vietnam, are complete and data are being compiled for submission.

**Developing improved East African highland banana varieties using biotechnology**

**Donor:** Ugandan Government, USAID, Belgian Government, Rockefeller Foundation

**Partners by country:** Belgium: KULeuven; France: CIRAD; South Africa: FABI-University of Pretoria; Uganda: IITA, Makerere University, NARO; UK: JIC

In 2000, in response to a request from the Ugandan Government and USAID, INIBAP set up a project to develop improved AAA East African highland bananas

## PRO*MUSA*

The Global Programme for *Musa* Improvement, PRO*MUSA*, brings together the world's six *Musa* breeding programmes and more than 100 researchers to focus on the smallholder crop. Working groups are devoted to Sigatoka, Fusarium wilt, Nematology, Weevil, Virology and Genetic improvement. Genomics consortia on banana and *Mycosphaerella* and a breeding consortium have also been launched. INIBAP provides the secretariat.

- The "First International Congress on *Musa*" organized by PRO*MUSA* and MARDI took place in Malaysia from 6 to 9 July 2004. Some 250 delegates, from both public and private research institutes as well as from the commercial sector, participated in the Congress. The theme "Harnessing research to improve livelihoods" was chosen to illustrate PRO*MUSA*'s commitment to knowledge building across disciplines and regions, which, in due course, should have a direct impact on improving the livelihoods of banana farmers and their communities throughout the world.
- The 4th PRO*MUSA* global meeting was held from 12 to 13 July 2004 in Malaysia. Each working group met to review scientific priorities and elect a convenor. The convenors are: Dirk De Waele, KULeuven (Nematology); Jaroslav Dolezel, IEB (Genetic improvement); Andrew Geering, QDPI (Virology); Cliff Gold, IITA (Weevil); Geert Kema, WAU (Sigatoka); Michael Pillay, IITA (Breeding) and Altus Viljoen, FABI (Fusarium).
- Two populations segregating for nematode resistance supplied by CIRAD have been evaluated in the field at CORBANA, Costa Rica.
- New hybrids from CARBAP, in Cameroon, have been sent to the ITC in Belgium for virus indexing and further evaluation.

(EAHB) through the use of biotechnology. The aims were to genetically modify eight cooking and brewing varieties to express resistance to nematodes, black Sigatoka and weevils, and to build Uganda's national capacity to use the current tools of biotechnology to develop high-yielding, pest- and disease-resistant varieties of this crop. Two laboratories for tissue culture and molecular research at NARO have been revamped and equipped and a team of researchers and technicians has been trained and guided through the process of establishing embryogenic cell suspensions with technical backstopping from KULeuven, CIRAD and JIC. Through the project, three Ugandan scientists are obtaining doctoral degrees and learning the latest techniques, while carrying out original research in gene discovery, evaluation and transformation of banana.

- Given the difficulty of reproducing the 'scalp technology using EAHB cultivars, it was decided in 2004 to concentrate on using male flowers to initiate cell suspensions. The male flowers of four of the eight originally selected cultivars – Mbwazirume, Nakinyika, Nakitembe and Mpologoma – are regularly used as starting material to initiate cell suspension cultures.
- Embryogenic calluses have been obtained for Mbwazirume and Nakinyika and cell suspensions initiated.

*Figure 3. Papaya cystatins (insert) were re-engineered and fed to weevils. The larvae fed the modified cystatins had significantly reduced growth (right) compared to the controls (left).*

- The cell suspensions of the AAB cultivar Sukali ndizi continue to perform well.
- *Agrobacterium*-mediated transformation of Sukali ndizi cell suspensions using the GUS marker gene was performed, confirming the applicability of the *Agrobacterium* transformation system developed at KULeuven.
- Equipment for cryopreservation was acquired and cryopreservation of cell suspensions started in February 2004. Seventeen cell lines have been cryopreserved, of which 13 were re-established in liquid medium. All the cell lines that established well in liquid medium (i.e. the cells multiplied and increased in volume) and maintained their embryogenic potential were less than 1 year old at the time of cryopreservation.
- The inhibitory action on development of banana weevil (*Cosmopolites sordidus*) of a papaya cystatin was enhanced by the generation of mutants with improved binding and stability (Figure 3). Based on an analysis of their amino acid sequences, 18 mutations were created and tested for their ability to inhibit digestive enzymes. In preliminary tests, inhibition was improved in 11 out of 18 mutant cystatins.
- A cDNA library was developed using plants artificially infested with weevil eggs and untreated plants. Various subtraction products were isolated and cloned. Inserts obtained after digestion with restriction enzymes were sequenced. The sequences seem to belong to a family of variable genes that might be involved in resistance to weevils.
- A technique allowing the nematodes *Radopholus similis* and *Pratylenchus coffeae* to take up substances from a liquid medium has been developed. This will enable the testing of various lectins and, as such, the identification of potential genes to control nematodes.

### Developing genetic transformation protocols

With funds from Belgium, INIBAP pursues studies to refine the protocols for developing and storing starting materials for genetic transformation and for optimizing the process of transformation. The

## Global *Musa* Genomics Consortium

**Partners by country:** Australia: DPIF, QUT, University of Queensland; Austria: ARC, FAO/IAEA; Belgium: KULeuven, UCL, University of Gent; University of Liege, University of Gembloux; Brazil: CENARGEN/EMBRAPA, Universidade Catolica de Brasilia; Czech Republic: IEB; Finland: Turku Centre for Biotechnology; France: CIRAD, INIBAP; Germany: MIPS/GSF; India: IIHR; Japan: NIAS; Malaysia: UM; Mexico: CICY, CINVESTAV; Nigeria: IITA; Uganda; IITA-ESARC; UK; University of Leicester; USA: Arizona State University, NSF, TIGR, University of Georgia; University of Minnesota

This Consortium brings together expertise from 30 publicly funded institutions in 16 countries. As well as encouraging close collaboration, the consortium enables research resources to be shared, including sequence data and enabling technologies. The sequence data produced by the Consortium will be placed in the public domain and any new varieties will be made freely available to smallholder farmers. The overall strategy of the Consortium is to adopt a step-wise approach, focusing on comparative genomics (based on the better-known genome of rice) and targeting gene discovery. INIBAP provides the secretariat. Funding is provided by the members through individual projects. Much of the Consortium activities are dependent on funding from the member institutes. Several regional groupings between members have also been established.

- The 3rd meeting of the Global *Musa* Genomics Consortium was held in Malaysia on 10 July and was attended by 22 participants from 12 countries.
- KULeuven has been suggested as the *Musa* Transgenic Resource Centre for the Consortium, i.e. to provide to partners plants transformed with their gene of interest and coordinate with interested partners the generation and the utilization of a mutant population by T-DNA insertion.

The Generation Challenge Programme, which became operational in 2004, has provided support for the activities of Consortium member in genetic diversity characterization, comparative genomics and bioinformatics.

Subprogramme Genetic Diversity:

- A first set of 48 accessions represented at the ITC and CIRAD field collection in Guadeloupe was selected for genotyping using SSR and IRAP markers. The DNA was extracted at CIRAD and sent to IAEA and the University of Leicester.
- The University of Leicester team analysed the 48 accessions using IRAP markers. The results were comparable to the ones obtained using other DNA-based markers and were obtained at less cost.
- FAO/IAEA developed 53 SSR markers from a small insert library enriched for SSR motifs and from BAC-end sequences. The reliability of these markers is being tested with the 48 accessions selected by the Consortium.
- A second set of 186 accessions mostly from the IITA collection was selected. The DNA extracted at IITA was sent to CIRAD and molecular characterization is being carried out by both institutes using 27 SSR markers.
- The 4th FAO/IAEA Interregional training course on Mutant germplasm characterization using molecular markers was held from 27 September to 22 October 2004 at the IAEA in Vienna, Austria. Support from the Generation Challenge Programme enabled various *Musa* researchers to participate.

Subprogramme Comparative Genomics:

- The University of Leicester team designed primers using conserved regions of orthologous genes. Some 80 primer pairs have been constructed and 360 sequences identified. A picture of genetic variability between accessions and the extent of gene conservation between *Musa* and other species is emerging.
- To identify COS markers common to rice/sorghum and *Musa*, 49 cDNA clones from sorghum and rice were used at CIRAD to screen the *Musa acuminata* Calcutta 4 BAC library. The use of heterologous RFLP probes from sorghum proved inadequate to create links between genetic maps of monocots.
- Two SSH cDNA libraries were constructed at CIRAD to better understand somaclonal variation and plant development.
- Gene expression profiling methods are being developed at IITA to identify markers for the selection of *Musa* accession with drought tolerance and high water use efficiency.

Subprogramme Bioinformatics:

- INIBAP organized an EST analysis workshop, where eight staff from member institutes in Brazil, India, Malaysia, Nigeria and France were trained to analyse their institutes EST sequences. The genomic data were made available in a web-based information portal on the Consortium web site. At the annual meeting of the GCP, special recognition was paid to INIBAP for its support to capacity building.
- A prototype, using the website technology BioMoby, has been developed to access the molecular characterization data in the CIRAD TropGENE online database using the accession identification number, effectively linking the passport data in MGIS with the molecular data in TropGENE.
- Laboratory Information Management System and SSR genotyping softwares were evaluated at Agropolis.

### *Musa* Genome Resource Centre

The *Musa* Genome Resources Centre based at the IEB in the Czech Republic has been active in distributing *Musa* genome resources to consortium members and in developing new resources. The aim of the resource centre is to provide DNA libraries, individual DNA clones, markers for molecular cytogenetics and high-density colony filters to the members of the Consortium. Three BAC libraries are available through the resource centre as 384- or 96-well plates or as high-density colony filters and, exceptionally, as single clones. A growing collection of repetitive DNA clones is also being maintained and characterized by copy number, genomic distribution in *Musa acuminata* and *Musa balbisiana*, and similarity to known DNA sequences. Cytogenetic markers available for distribution include those for 5S and 45S ribosomal RNA loci. New cytogenetic markers based on BAC clones isolated from genomic libraries are being developed.

A framework agreement is being prepared to consolidate the sharing of resources and information among Consortium members.

## International *Mycosphaerella* Genomics Consortium

**Partners by country:** Brazil: EMBRAPA; Cuba: IBP; France: CIRAD; Mexico: CICY; Netherlands: PRI; Switzerland: ETH; USA: BTI

The International *Mycosphaerella* Genomics Consortium brings together seven partners from seven countries who have a shared research interest in *Mycosphaerella* species. Present activities aim to build a collection of *Mycosphaerella* isolates, mapping populations and transgenic strains at CIRAD, under the auspices of INIBAP, to be made available to the banana research community.

- The International *Mycosphaerella* Genomics Consortium members met in Malaysia on 9 July 2004. The development of a web site was discussed and it was proposed that the international collection of *Mycosphaerella* pathogens attacking bananas (*M. fijiensis*, *M. musicola* and *M. eumusae*) be based at CIRAD, under the auspices of INIBAP. The CIRAD collection already includes *Mycosphaerella* banana pathogens, as well as mapping populations and transgenic strains.
- IPB and the University of Hamburg are studying *Mycosphaerella fijiensis*-banana interactions, using cDNA libraries obtained from Calcutta 4 plants at an early stage of infection and from Niyarma yik plants at a late stage of infection.
- At CIRAD-AMIS, three $F_1$ populations were obtained by crossing isolates from Cameroon, Columbia, Mexico and the Philippines and are being screened using markers from *M. fijiensis, M. grisea* and *M. graminicola*.

research takes place at the Laboratory for Tropical Crop Improvement at KULeuven.

- In 2004, 13 cryopreservation experiments on 8 cell lines each were conducted. For each cell line, an average of 8 cryotubes was transferred to the liquid nitrogen tank. After careful screening of all cryotubes, 623 remain stored for the long term. In total, there are now 2140 cryotubes stored in liquid nitrogen containing transformation competent cell lines of 13 cultivars (Table 1).
- Conventional and new methods to prepare embryogenesis-competent explants were used on Calcutta 4, Williams, Ingarama, Orishele and Cachaco. The quality of the cultures was scored from very low (-) to very high (++++) depending on the proportion of meristematic tissue to corm and leaf tissue. According to the time required to obtain 50 optimized multiple meristem cultures (i.e. cultures whose quality could not be further improved), the gain of time with the new method was 1 month for Cachaco, 3 for Calcutta 4, 5 for both Williams and Ingarama and 6 for Orishele. The morphological characteristics of the cultures, however, were similar, except for Calcutta 4 and Ingarama, which were slightly improved using the new method.
- Several promoter tagging vectors containing the codon-optimized luciferase (*luc*+) reporter gene close to the border of the T-DNA have been developed. These constructs increased the activity of the luciferase enzyme and the tagging frequency 40-fold in the varieties Three hand planty, Williams and Cacambou, compared to the wild-type luciferase gene. These constructs significantly increased the efficiency of the large-scale search for banana promoters. As a result, 40 000 cell colonies can be screened in a week.
- The 10 196 gene-specific tags generated from leaf cDNA after performing SuperSAGE represent 5292 expressed genes, of which 83% occurred only once, a very low frequency.
- Despite the poor results obtained when using xylose to select transgenic plants of Three hand planty, the *xylA* gene was further tested by introducing it into embryogenic cell suspensions of the dessert banana Gros Michel. The regeneration frequency was only improved when sucrose was added to the selection system. It was concluded that xylose is not suitable for efficient selection of transgenic banana plants. Preliminary results also indicate that mannose and the phosphomannose isomerase gene do not provide suitable selection systems.

**Table 1. Cryopreserved suspensions that are currently safely stored for the long term.**

| Cultivar | Genomic group | Number of independent cell lines stored in liquid nitrogen |
|---|---|---|
| Agbagba | AAB plantain | 4 |
| Three hand planty | AAB plantain | 6 |
| Orishele | AAB plantain | 10 |
| Obino l'ewai | AAB plantain | 1 |
| Dominico | AAB plantain | 2 |
| Bisé egomé | AAB plantain | 2 |
| Bluggoe | ABB | 6 |
| Cacambou | ABB | 16 |
| Cachaco | ABB | 5 |
| Dole | ABB | 8 |
| Grande naine | AAA | 11 |
| Gros Michel | AAA | 1 |
| Williams | AAA | 24 |

# INIBAP around the world

INIBAP and its partners carry out a wide range of activities and individual projects in banana-producing regions, touching many points in the continuum from advanced research to capacity building and community-level activities. The regional offices and their coordination of the regional banana networks underpin INIBAP's work in the regions. Thus, each of the regional networks for which INIBAP provides the secretariat – *MUSA*LAC, BAPNET, BARNESA and *MUSA*CO – has a steering committee that meets regularly to identify priorities. Many of INIBAP's projects channel funds towards priorities that have been identified by the networks, and the network members usually act as implementing partners.

## Inter-regional projects

### Farmer participatory evaluation and dissemination of improved *Musa* germplasm

**Donor:** CFC

**Partners by country:** DRC: INERA ; Ecuador: FUNDAGRO; France: CIRAD; Haiti: IICA; Guinea: IRAG; Honduras: FHIA; Nicaragua: UNAN-Leon; Uganda: NARO

**Aims:** To identify 2-3 improved varieties resistant to black leaf streak disease, fusarium wilt and nematodes through a strengthened national system for variety evaluation based on farmer participation, and to establish a supply of clean planting material.

**Activities in 2004:**

- Data on the first ratoon crop were collected from the 31 demonstration plots set up in the 7 participating countries during the previous year.
- Farmers participated in 14 taste tests to evaluate the eating qualities of the improved varieties.
- Farmer preference was found to be based on bunch size, eating quality and market value.
- Farmers and field technicians in DRC, Guinea, Nicaragua and Uganda monitored cultivar performance in the farmer plots established in the previous year.
- Country partners in Honduras, Uganda, Ecuador and Nicaragua established an additional 200 farmer multiplication plots.
- Selected partners undertook studies and activities to orient new projects and programmes based on the preferred varieties. In Guinea, an innovative market study, based on the evolution of the price per bunch, was conducted. In Nicaragua, test plots were set up to look at the performance of improved hybrids in dry zone production systems and in association with coffee. In Uganda, student theses were started to look at credit feasibility and seed multiplication techniques. In Ecuador, partners from the agro-industry sector were brought in to study the improved varieties as ingredients in snack foods.

### Increasing productivity and market opportunities for banana and plantain

**Donor:** USAID TARGET

**Partners by country:** Cameroon: CARBAP, Cameroon Gatsby Trust; Ghana: CSIR, WV Ghana; Mozambique: INIA, AFRICARE, CARE, Ministry of Works, UEM, *Casa do Gaiatus*; Tanzania: ADRA, ARDI, FAIDA. This work is jointly implemented by IITA and INIBAP.

**Aims:** To promote improved varieties and production techniques and raise rural income through community-based activities.

**Activities in 2004:**

- Country partners in Tanzania and Mozambique distributed between 20 and 50 plants of 4 varieties to over 950 farmers. These farmers were trained on improved production techniques and rapid multiplication techniques. They were also trained on marketing and were assisted in forming producer organizations.
- Country partners in Ghana and Cameroon began distributing suckers obtained from first-year farmers to 400 new farmers They monitored the growth of the varieties planted during the first year and organized training sessions on rapid multiplication techniques.
- Country partners carried out a preliminary impact survey to determine which varieties were being multiplied by farmers. They also collected testimonials from farmers to illustrate the potential economic contribution of improved varieties and production techniques. These studies will be completed in early 2005 as part of a no-cost extension of the project.

## Latin America and the Caribbean

### Organic banana production in Bolivia

**Donor:** Inter-American Drug Abuse Control Commission of the Organization of American States

**Partners by country:** Bolivia: VIMDESALT, banana farmer associations

**Aims:** To rehabilitate banana production in the Alto Beni region of Bolivia through the use of strengthened farmer associations and the development of organic production for urban and international markets.

**Activities in 2004:**

- The 2-year project ended in May. A 6-month transition phase was approved to set the stage for a second phase of the project, which will start in 2005 but for which INIBAP will no longer play a coordinating role.
- As a result of the project, the participating farmers have been organized in ten producers associations and now own a commercialization enterprise, Bana Beni SRL, which has its own building, equipment and other facilities. Some of the producers' children were trained in relevant business skills and are now running Bana Beni.

### *MUSA*LAC meetings, training and other activities

The Plantain and Banana Research and Development Network for Latin America and the Caribbean (*MUSA*LAC) operates under the auspices of the *Foro Regional de Investigación y Desarrollo Tecnológico Agropecuario para América Latina y el Caribe* and is coordinated by INIBAP in Costa Rica.

- The *MUSA*LAC Steering Committee meeting was held in October and attended by 43 participants from 15 countries.
- INIBAP-LAC organized an international workshop on "Biotechnology applied to *Musa*" under the umbrella of REDBIO 2004. The meeting took place in Santo Domingo, Dominican Republic, 21-25 June 2004. More than 60 scientists from around the world attended.
- A training course on "Experimental design applied to banana and plantain" took place in San Jose, Costa Rica, 6-11 June 2004. INIBAP-LAC produced a training manual for the 30 participants attending.
- Training courses on *Musa* production were given in Bolivia, Colombia, Mexico and Peru. Most of the participants were farmers and extension personnel. Nearly 400 participants attended these courses.

- More than 1000 hectares of organic bananas have been upgraded and close to 600 farmers have benefited from this effort.
- Agronomists were trained and appointed to individual farmer associations and farmers were trained in various production technologies.
- Organic production guides were developed.
- Irrigation, cableways, packing stations, transport and ripening stations have been put in place to improve the quality of the fruit and increase the quantity processed.
- Sales are in the neighbourhood of 12 000 boxes per month. Bana Beni has captured 85% of the school breakfast market in La Paz and El Alto.

### Development of plantain cultivars resistant to black Sigatoka for Latin America

**Donor:** FONTAGRO

**Partners by country:** Colombia: CIB-UNALMED; Costa Rica: CORBANA, CATIE, University of Tolima; Mexico: CINVESTAV

**Aims:** To improve plantain production in Latin America by using genetic transformation methods to develop new resistant cultivars and through the use of a fast evaluation system for detecting black Sigatoka resistance under controlled conditions.

**Activities in 2004:**

- This project ended in December. A reliable protocol for producing plantain embryogenic cell suspensions and transforming them has been adapted for use in Latin America. Constructs and vectors for carrying out the transformation have been identified.
- The transformed plants are under evaluation for black Sigatoka resistance in the greenhouse and the promising candidates will be transferred to the field in 2005.

### Development and use of bioproducts to control nematodes and black Sigatoka

**Donor:** FONTAGRO

**Partners by country:** Costa Rica: CATIE; Dominican Republic: IDIAF; Panama: IDIAP; Venezuela: INIA

**Aims:** To develop new bioproducts and clean technologies to control nematodes and black Sigatoka.

**Activities in 2004:**

- This 5-year project started in 2004. The field-testing of elite products and technologies will take place in Costa Rica, Dominican Republic, Panama and Venezuela, and specialized laboratories in Austria and Germany are also participating. The emphasis of the project is on soil and environmental health.
- The 22 scientist and technicians from the four participating countries attended an immersion workshop held at CATIE in Costa Rica.

## Asia and the Pacific

### National repository, multiplication and dissemination centres

**Donors:** European Union, the Philippines and Taiwan Governments

**Partners by country:** Bangladesh: BARI; Cambodia: CARDI; China: SCAU, GDAAS, CATAS; South Pacific countries: SPC; India: NRCB; Indonesia: ICHORD, IFRURI; Malaysia: MARDI; Myanmar: FTRC, MAS; Papua New Guinea: NARI; Philippines: BPI, IPB; Sri Lanka: HORDI; Taiwan: TBRI; Thailand: HRI; Vietnam: VASI

**Aims:** To enable countries to supply clean planting material of improved and local varieties to researchers and farmers on a large scale.

**Activities in 2004:**

- The NRMDCs are operational in Bangladesh, Cambodia, China, Fiji, India, Indonesia, Malaysia, Myanmar, Papua New Guinea, the Philippinesn Sri Lanka, Taiwan, Thailand and Vietnam.
- The NMRDCs are used as the platform for national banana rehabilitation programmes in Bangladesh, the Philippines, Sri Lanka and Vietnam.

### Support to the national banana programme (of the Philippines)

(*For more information see the article "Bringing back an old favourite, the capitalist way" on page 20.*)

**Donor:** DA-BAR

**Partners by country:** Philippines: BPI, CvSU, DMMMSU, IPB, ISPSC, MinSCAT, PAC, PCARRD, QSC, Rotary Club, SLPC, Virlanie Foundation

**Aims:** To provide farmers with clean planting material of improved varieties and knowledge on how to grow them.

## BAPNET meetings, training and other activities

The Banana Asia and Pacific Network (BAPNET) operates under the auspices of the Asia Pacific Association of Agricultural Research Institutes and is coordinated by INIBAP in the Philippines.

- The Steering Committee meeting was held in Indonesia in October.
- A training workshop on recent advances in eco-friendly management of nematodes was held, 16-18 March 2004, at the NRCB in Tiruchirapalli, India.
- A regional workshop on "Sustainable banana production through the use of clean planting material" was held in Ho Chi Minh City, Vietnam, on 4-6 October 2004. Thirty-nine participants attended the workshop, 20 from Vietnam and 19 from other BAPNET member countries.
- A seminar on "Postharvest technology to improve the quality of bananas" was held on 7 October 2004 at the Southern Fruit Research Institute in Vietnam.
- A training workshop on the "Management of diseases and the use of disease-free planting material" was held in Sri Lanka, 28-29 October 2004. Researchers from government and private laboratories, as well as growers attended the training.

**Activities in 2004:**

- As part of this project, a distribution system of tissue culture planting material was established, whereby a private laboratory sells rooted plantlets to local nurseries, which grow them and sell them as ready-to-plant material to farmers. Various public sector institutions, such as state universities, provide technical support, with backstopping from INIBAP.
- A total of 77 500 plantlets have been distributed to collaborators. Growers and technicians from the participating institutions were trained on how to grow the plantlets in the nursery and in the field. The agronomic performance of these varieties is recorded.

### Use of cultivar diversity for sustainable disease management

**Donors:** Unrestricted funds, EU

**Partners by country:** Philippines: CvSU, DMMMSU, PCARRD, QSC

**Aims:** To quantify the impact of cultivar diversity on yield and disease severity.

**Activities in 2004:**

- Meetings were held to discuss the design of the field experiments which will be implemented in three state colleges and universities. The plant materials, popular local cultivars and improved varieties, have been delivered.

### Nematode studies

**Donor:** VVOB

**Partners by country:** Philippines: IPB

**Aims:** To investigate sources of nematode resistance and build capacity in India and the Philippines to conduct nematological studies.

**Activities in 2004:**

- A nematological survey was conducted in Quezon and Mindoro province, in the course of which 247 root samples from 16 cultivars were collected.
- Two screening experiments were finished and another two were initiated.
- A Filipino student at KULeuven is comparing populations of *Radopholus similis* from the Philippines with other populations.
- In India, one of two PhD students has obtained seeds from crosses intended to confer nematode resistance and the resulting seedlings were planted in the field.

## Eastern and Southern Africa

### On-farm conservation

(*For more information see the article "Reconciling modernity and tradition to conserve diversity" on page 4*).

**Donor:** IDRC

**Partners by country:** Tanzania: ARDI, Farmer Associations from Bisheshe, Chanika and Ibwera; Uganda: farmers associations from Bushenyi and Masaka, Makerere University, NARO, Ssemwanga Center for Food and Agriculture, VI Agroforestry project, Uganda Biodiversity Network, FADECO

**Aims:** To strengthen banana-based biodiversity conservation strategies and improve the livelihoods of smallholders by broadening the utilization base of the crop.

**Activities in 2004:**

- Preliminary results on gender roles indicate that men tend to take responsibility for the commercial production of banana whereas women tend the subsistence crop.
- The potential and training needs of the participating farmers associations with regards to product development have been identified.
- Three of the associations supported by the project have expanded their market or created new ones for their banana-based products.
- A trade fair showcasing diversity was conducted in Nairobi in April.

## BARNESA meetings, training and other activities

The Banana Research Network for Eastern and Southern Africa (BARNESA) operates under the auspices of the Association for Strengthening Agricultural Research in Eastern and Central Africa with funding from the EU. It is coordinated by the INIBAP Regional Coordinator for Eastern and Southern Africa, with administrative support from the INIBAP-ESA office.

- A training course on proposal writing, attended by 27 scientists from BARNESA member countries, was held in Ethiopia; three concept notes were drafted as part of the training course. The participants were exposed to team building and multi-disciplinary approaches. They also exchanged ideas and developed linkages with other banana scientists from the region. This is expected to improve the work interactions between BARNESA members.
- Researchers and extensionists from the Great Lakes region met in Rwanda on 15-17 August to analyse the state of research and development on banana and identify research priorities. A concept note was developed to feed into the development of the DGDC project involving the three Great Lakes countries (Rwanda, Burundi and DR-Congo).

- The awareness of farmers regarding the role and importance of the various plants and animals associated with banana production systems has been raised.
- An inventory of banana clones was conducted.
- The scientific basis of Indigenous Knowledge practices regarding banana diversity is being assessed.
- Germplasm curators from Burundi, DR-Congo, Kenya, Rwanda, Tanzania and Uganda were trained in banana taxonomy as a basis for uncovering synonyms.
- Fingerprinting of EAHB clones using SSR primers has been initiated.

### Assessing impact of improved hybrids on livelihoods

**Donor:** IFAD, Rockefeller Foundation, USAID

**Partners by country:** Tanzania: ARDI, Sokoine University; Uganda: IITA, Makerere University, NARO; USA: IFPRI

**Aims:** To examine the sociological and economic impacts of improved varieties of banana on the livelihoods of smallholder farmers and to build capacity in NARS and universities to carry out multi-disciplinary impact studies using the sustainable livelihoods approach.

**Activities in 2004:**

- Three MA students, after carrying out field studies on the impact of improved cultivars on gender relations, human health and farmers' human capital, began their data analysis.
- The impact assessment working group of 19 people representing NARO, Makerere University, ARDI, IFPRI, IITA and INIBAP met for two days in November to review research results from the 42 villages surveyed in Uganda and Tanzania and to plan the work for the final year of the project.
- An INIBAP team worked with Makerere University and NARO scientists in developing methods to document organizational perspectives on the possible uses of impact assessment studies. They tested a format to inventory the implementation activities and distribution methods used in villages to determine their respective importance for impact. Farmer focus groups were also piloted to document the social, economic and political changes occurring in the villages at the time the improved varieties were being distributed. This work is funded by the ILAC initiative, a CGIAR System-wide Programme.

### Root system growth and disease in bananas and enset

**Donor:** VVOB

**Partners by country:** Ethiopia: SARI; Uganda: NARO, University of Makerere

**Aims:** To understand the variability in root growth and shoot-root relationships in highland banana genotypes and assess the influence of pests and diseases on root and shoot growth of enset and banana genotypes.

**Activities in 2004:**

- The on-farm and on-station trials on the development of the root system of EAHB cultivars were completed and the data analysed. Two MSc students involved will defend their theses in 2005.
- Research and development activities on enset and banana have been initiated in Ethiopia. Scientists from various organizations compiled a list of publications on enset and entered them into a database.
- A VVOB-sponsored MSc student carried out a survey of pests and diseases in the main enset- and banana-growing regions of Ethiopia.

## West and Central Africa

### Improving periurban production

**Donor:** Government of France

**Partners by country:** Benin: INRAB, CARDER; Ghana: CSIR, University of Ghana

**Aims:** To evaluate disease resistant, tolerant and high-yielding plantain and banana hybrids in periurban zones and to train farmers in rapid multiplication techniques.

**Activities in 2004:**

- The agronomic performance of FHIA-25, FHIA-23, FHIA-18 and CRBP 39, which are resistant to black Sigatoka, was evaluated by 40 farmers in each periurban zone – of Kumasi and Sekondi-Takoradi in Ghana, and Cotonou in Benin. In both countries, the productivity of FHIA-25, FHIA-23 and FHIA-18 was high and the farmers liked the hybrids. In Benin, the productivity of CRBP 39 did not exceed that of the cultivars Aloga and Orishele. In Ghana, the CRBP 39 plants were destroyed because they were infected with BSV.
- In Kumasi, Ghana, 106 farmers, technicians and extensionists, half of whom were women, were trained on a rapid multiplication technique using corms by CARBAP scientists.
- In Benin, 120 participants were trained on a sucker multiplication technique and on the establishment and management of banana plots.
- The project ended in 2004.

### Evaluating plantain production at high planting densities

(*For more information see the article "When West Africa meets Latin America" on page 10*).

**Donor:** INIBAP unrestricted funds

**Partners by country:** Cameroon: CARBAP, Côte d'Ivoire: CNRA

**Aims:** To optimize the high-density planting techniques that West African farmers and researchers learned on a CTA- and INIBAP-sponsored visit to the Dominican Republic and Costa Rica in 2001.

**Activities in 2004:**

- The pilot studies in Cameroon and Côte d'Ivoire have clearly demonstrated the potential of this cropping system to provide higher yields in West and Central Africa.
- At the peak of vegetative development, the dense canopies in the high density plots drastically reduced the quantity of sun reaching the ground, virtually eliminating weed growth.
- The plot sizes used in these trials were too small to generate the microclimatic conditions that inhibit or retard the development and expression of black leaf streak disease. Thus a fungicidal treatment was necessary to control the disease, resulting in higher yields in the treated plots compared to the untreated ones, irrespective of planting density.
- The number of fingers per bunch and bunch weight declined with increased planting density. However, because the number of bunches harvested was greater in the high density plots, yields were higher in the 2500 and 3300 plants/ha plots than in the conventional, lower-density plots.

### Nematode studies in Cameroon

**Donor:** CARBAP and VVOB

**Partners by country:** CARBAP, IITA

**Aims:** To investigate the importance of the nematode *Pratylenchus goodeyi* in banana production in the Western and Northwestern provinces of Cameroon.

**Activities in 2004:**

- Over 200 households were interviewed to determine the importance of banana and plantain, the most common cropping associations, and the management strategies used, as well as to evaluate the level of awareness of pests.
- The results of this survey have led to the identification of a number of technologies adapted to the region, which are currently under evaluation in selected farmers' fields.

### *MUSA*CO meetings, training and other activities

The *Musa* Research Network for West and Central Africa (*MUSA*CO) operates under the auspices of the West and Central African Council for Agricultural Research and Development. It is coordinated by INIBAP in Cameroon.

- A Steering Committee meeting was held in Cameroon in June 2004.
- Farmers in the Northwestern province of Cameroon were surveyed to determine research and development priorities.

# Sharing information

All INIBAP staff plays a role in communicating research findings and new technical information to scientists and farmers; they are also involved in raising the public's awareness of banana as a staple food and of the necessity for research and development to make the best use of banana diversity. The following summary represents only the activities of INIBAP's information and communications group in 2004.

#### The virtual library

*MUSA*LIT now includes 9038 bibliographic abstracts in 3 languages:

- 40% of the references in the *MUSA*LIT database are linked to their full text documents and more than 1000 articles, factsheets, reports and books published by INIBAP in English, Spanish and French are now electronically available through INIBAP's website and on the *MUSA*DOC 2004 CD-Rom
- 645 new records were added to *MUSA*LIT.
- 696 information requests were processed in 2004.
- The *MUSA*DOC 2004 CD-Rom was published in October and distributed to 1500 users.
- The BRIS database of banana researchers now contains 913 records, including 43 new records.

#### INIBAP on the internet

- The entire INIBAP web site has been redesigned, redeployed under PHP technology and was relaunched on 30 September 2004.
- The average daily number of visits increased to 476, from last year's 351.
- 53 500 Mb of publications were downloaded.
- The Global *Musa* Genomics Consortium web site, hosted by INIBAP, was launched in June 2004. A link to the *Musa* Genome Resource Centre was created so that members can access information on the available genomics resources and request materials online.

#### Publications

- Two issues of INFO*MUSA* were produced. A reader survey showed a high level of satisfaction among the 326 respondents (over 12% of individual subscribers). Forty-one percent of the respondents were from the Latin America and Caribbean region, 27% from Africa, 19% from Asia, 7% from Europe, 3% from the Pacific Islands, 1.5% from North America and 1.5 % from the Middle East. (Table 2)
- The extended abstracts of the International Congress on *Musa*, held in Malaysia in July 2004, were distributed at the congress.
- A 392-page book entitled "Banana improvement, cellular, molecular biology and induced mutations" was copublished by FAO/IAEA and INIBAP. Edited by S. Mohan Jain and R. Swennen, it presents the results from the FAO/IAEA-coordinated research project entitled "Cellular biology and

**Table 2. Highlights from the INFO*MUSA* reader survey.**

| How would you rate INFOMUSA? | Weak | Average | Strong |
|---|---|---|---|
| Useful in keeping up with research on *Musa* | | 20% | 80% |
| Mix of upstream and downstream research | 3% | 48% | 49% |
| Emphasis on problems relevant to the poor | 10% | 50% | 40% |
| Quality of the scientific content | 3% | 32% | 65% |
| Quality of the writing | | 28% | 72% |
| Quality of the presentation | 2% | 22% | 76% |
| **How do you rate the importance of the following?** | Not important | Important | Very important |
| Cross-regional coverage | 1% | 40% | 59% |
| Availability in three languages | 4% | 31% | 65% |
| Availability in print | 1% | 25% | 74% |
| Articles on upstream research | 1% | 45% | 54% |
| Articles on downstream research | 1% | 34% | 65% |
| Readability | | 31% | 79% |
| High scientific standards | 1% | 35% | 64% |
| Presentation | 1% | 33% | 66% |
| **Are you satisfied with the spectrum of articles or would you like to more or fewer articles in the following categories?** | More | Fine as is | Less |
| Cultural practices | 49% | 49% | 2% |
| Genetic transformation | 31% | 57% | 12% |
| Germplasm screening | 31% | 60% | 8% |
| Integrated pest management | 62% | 32% | 2% |
| Uses and products | 54% | 41% | 5% |
| Socioeconomic studies | 41% | 52% | 7% |
| Pests and diseases | 60% | 38% | 2% |
| Tissue culture | 40% | 52% | 8% |
| Molecular biology | 34% | 53% | 13% |

biotechnology including mutation techniques for creation of new useful banana genotypes".

## Raising awareness

- The format of the annual report was changed to include four feature-length articles on the impact of selected projects and a summary of the year's project activities. For the first time, the entire document was translated into French and Spanish and three linguistic versions were published.
- Plans for a travelling exhibition on the future of banana diversity and banana research, to be produced in collaboration with CIRAD and the Eden Project, were further developed. A presentation on the exhibition at the Botanic Gardens Congress in Barcelona was received with interest and is expected to result in the identification of additional venues, when the exhibition goes on tour in 2005/2006.
- Personal accounts of the importance of banana were gathered from farmers involved in the TARGET project.
- A press release on the banana Congress in Malaysia resulted in significant press interest in research on the vitamin A content of Fei bananas.

## Regional information networks

- Information partnerships were strengthened with various African networks, including ASARECA-RAIN, CORAF/WECARD, FARA and SACCAR.
- An information training course for French-speaking documentalists was held at CARBAP in November. Sixteen trainees from 12 African countries participated.
- The regional documentation centre set up at CARBAP, Cameroon, is operational.
- Three issues of the RISBAP Newsletter for Asia and the Pacific were published.
- The African information network contributed 102 bibliographic records to the *MUSA*LIT database and the Asia-Pacific network 32.

# INIBAP publications

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*Molina A.B*. Overview of the banana RDE programme. Banana R&D review and planning workshop. PCARRD, Los Baños, Laguna, Philippines, 28-29 April 2004.

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*Vilarinhos A.D.,* A. Benabdelmouna, F. Bakry, P. Piffanelli, D. Triaire, P. Lagoda, J.L. Noyer, B. Courtois, F. Carreel and A. DHont. 2004. Characterization of translocations in 'Calcutta 4' and 'Madang'. P. 25 *in* Harnessing research to improve livelihoods. Abstract guide. 1st International congress on *Musa*. Penang, Malaysia, 6-9 July 2004. INIBAP, Montpellier.

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*Van den Bergh I.* Culturing of *Musa* nematodes. Presentation given during the Training workshop: Recent advances for eco-friendly management of nematodes in banana, NRCB, Tiruchirapalli, India, 16-18 March 2004.

*Van den Bergh I.* Assessment of host-plant reaction of *Musa* to nematodes. Presentation given during the Training-workshop: Recent advances for eco-friendly management of nematodes in banana, NRCB, Tiruchirapalli, India, 16-18 March 2004.

*Van den Bergh I.* Overview of the banana rehabilitation programme. Presented during the hands-on training on Nursery and field management of *in vitro* propagated bananas, PAC, Magalang, Pampanga, Philippines, 18-19 May 2004.

*Van den Bergh I.* From nursery to the field: the big step. Presentation given during the hands-on training on Nursery and field management of *in vitro* propagated bananas, PAC, Magalang, Pampanga, Philippines, 18-19 May 2004.

*Van den Bergh I.* Proper field management: the road to success. Presentation given during the hands-on training on Nursery and field management of *in vitro* propagated bananas, PAC, Magalang, Pampanga, Philippines, 18-19 May 2004.

*Van den Bergh I.* Overview of the banana rehabilitation program. Presentation during the hands-on training on Nursery and field management of *in vitro* propagated bananas, MinSCAT, Victoria, Oriental Mindoro, Philippines, 25-26 May 2004.

*Van den Bergh I.* From nursery to the field: the big step. Lecture given during the hands-on training on Nursery and field management of *in vitro* propagated bananas, MinSCAT, Victoria, Oriental Mindoro, Philippines, 25-26 May 2004.

*Van den Bergh I.* Proper field management: the road to success. Presentation given during the hands-on training on Nursery and field management of *in vitro* propagated bananas, MinSCAT, Victoria, Oriental Mindoro, Philippines, 25-26 May 2004.

*Van den Bergh I.* and *M.A.G. Maghuyop.* Nematode pests of *Musa*: General information, diagnosis and management. Presentation given during the Training on Banana disease management and data collection, PCARRD, Los Baños, Laguna, Philippines, 10-12 August 2004.

*Van den Bergh I., M.A.G. Maghuyop, V.N. Roa* and *A.B. Molina.* 2004. The national repository, multiplication and dissemination centers: an instrument to enhance the distribution of improved, pest-and disease-resistant *Musa* varieties in Asia and the Pacific. 35th Anniversary and Annual Scientific Conference of the Pest Management Council of the Philippines, Iloilo, Philippines, 16-19 March 2004.

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■ **Dr Florence Wambugu**
Director, Regional Office
A Harvest Biotech Foundation International
AHBFI
Runda Mimosa vale
Hse No. 215
P.O. Box 25556, Nairobi
Kenya

## Financial Highlights

### Revenue

| | Unrestricted | Restricted | Total |
|---|---|---|---|
| Australia | 131 | | 131 |
| Austria | | 62 | 62 |
| Belgium | 234 | 773 | 1 008 |
| Canada | 592 | | 592 |
| European Union | | 650 | 650 |
| France | 166 | | 166 |
| India | 25 | | 25 |
| Netherlands | 82 | | 82 |
| Philippines | 8 | 65 | 73 |
| South Africa | 30 | | 30 |
| Thailand | 3 | | 3 |
| Uganda | | 188 | 188 |
| United Kingdom | 93 | 3 | 95 |
| USA | 77 | 140 | 217 |
| CATIE | | 16 | 16 |
| CDC | | 283 | 283 |
| CFC | | 340 | 340 |
| CIMMYT (Challenge Programme) | | 245 | 245 |
| CIRAD | | 31 | 31 |
| CTA | | 134 | 134 |
| FFTC | | 10 | 10 |
| FONTAGRO | | 232 | 232 |
| Gatsby Foundation | | 367 | 367 |
| IBRD | 551 | | 551 |
| IDRC | | 112 | 112 |
| IFPRI | | 31 | 31 |
| KULeuven | | 8 | 8 |
| OAS | | 562 | 562 |
| Rockefeller Foundation | | 73 | 73 |
| TBRI | | 2 | 2 |
| VVOB | | 476 | 476 |
| Other income | (51) | | (51) |
| **Total revenues** | **1 940** | **4 802** | **6 742** |

### Expenditures

| | Unrestricted | Restricted | Total |
|---|---|---|---|
| Research programme | 1 928 | 4 802 | 6 730 |
| General administration | 397 | | 397 |
| **Total Expenditures** | **2 325** | **4 802** | **7 127** |
| Recovery of indirect costs | (401) | | (401) |
| **Total** | **1 924** | **4 802** | **6 726** |

*As at December 31, 2004 – in US dollars ('000)*

## Staff List 2004

| | Name | Position | Nationality | Joined | Stationed |
|---|---|---|---|---|---|
| R. | Markham | Director | UK | 01-07-03 | Montpellier |
| A. | Akokulya* | Driver/messenger | Uganda | 01-01-03 | Uganda |
| E. | Akyeampong | Regional Coordinator WCA | Ghana | 01-06-97 | Cameroon |
| E. | Arnaud | Officer in charge of MGIS | France | 01-10-89 | Montpellier |
| T. | Aourai | Accounting Assistant | UK | 01-07-03 | Montpellier |
| S. | Belalcázar | Honorary Research Fellow | Colombia | 01-04-02 | Costa Rica |
| G. | Blomme | Associate Scientist, Assistant to Regional Coordinator | Belgium | 01-01-00 | Uganda |
| R. | Bogaerts | Technician | Belgium | 12-02-88 | ITC, Belgium |
| G. | Boussou | Info/Doc Specialist | France | 07-09-00 | Montpellier |
| H. | Calderon | Administrative officer | Costa Rica | 06-09-04 | Costa Rica |
| A. | Causse | Programme Assistant | France | 22-11-99 | Montpellier |
| H. | Doco | Info/Com Specialist | France | 15-09-98 | Montpellier |
| C. | Eledu | GIS Expert | Uganda | 01-06-00 | Uganda |
| L. | Er-Rachiq | Assistant Documentalist | France | 19-08-02 | Montpellier |
| J.V. | Escalant | Senior Scientist, Coordinator *Musa* Genetic Improvement | France | 01-04-99 | Montpellier |
| S. | Faure | Senior Programme Assistant | UK | 01-06-88 | Montpellier |
| L. | Fauveau* | Website Specialist, Consultant | France | 03-11-03 | Montpellier |
| E. | Gonnord | Accountant | France | 17-08-98 | Montpellier |
| K. | Jacobsen | Associate Scientist, *Musa* Technology Transfer | Belgium | 01-05-01 | Cameroon |
| J. | Kamulindwa | Administrator of the Ugandan Biotechnology Project | Uganda | 03-05-01 | Uganda |
| D. | Karamura | *Musa* Germplasm Specialist | Uganda | 01-01-00 | Uganda |
| E. | Karamura | Regional Coordinator ESA | Uganda | 01-04-97 | Uganda |
| E. | Kempenaers | Research Technician | Belgium | 15-10-90 | ITC, Belgium |
| K. | Lehrer | Programme Assistant | USA | 06-01-03 | Montpellier |
| C. | Lusty | Strategy Development Specialist | UK | 05-06-00 | Montpellier |
| S.B. | Lwasa | Programme Assistant | Uganda | 01-08-97 | Uganda |
| M.A. | Maghuyop | Technical Assistant | Philippines | 01-07-00 | Philippines |
| D. | Masegosa | Assistant Accountant | France | 16-08-04 | Montpellier |
| H. | Mbuga | Accounting Assistant | Uganda | 15-04-02 | Uganda |
| J. | Mertens | Technician | Belgium | 01-01-05 | ITC, Belgium |
| B. | Metoh | Programme Assistant | Cameroon | 07-01-03 | Cameroon |
| T. | Moens* | Associate Scientist, Nematology | Belgium | 01-06-98 | Costa Rica |
| A.B. | Molina | Regional Coordinator ASP | Philippines | 20-02-98 | Philippines |
| A. | Nkakwa Attey | Supervisor Plantation Technology Transfer Project | Cameroon | 01-11-02 | Cameroon |
| M. | Osiru | Associate Scientist | Uganda | 01-07-04 | Uganda |
| C. | Picq | Coordinator, Information/Communications | France | 01-04-87 | Montpellier |
| L. | Pocasangre | Associate Scientist, *Musa* Technology Transfer | Honduras | 01-07-00 | Costa Rica |
| G. | Ponsioen | Info/Doc Specialist | Netherlands | 12-04-99 | Montpellier |
| V. | Roa | Programme Assistant | Philippines | 01-01-91 | Philippines |
| F. | Rosales | Regional Coordinator LAC | Honduras | 01-04-97 | Costa Rica |
| M. | Rouard | Bioinformatician | France | 01-11-04 | Montpellier |
| N. | Roux | Scientist, Coordinator *Musa* Genomics and Genetic Resources | Belgium | 26-05-03 | Montpellier |
| M. | Ruas | Computer Technology Specialist | France | 28-02-00 | Montpellier |
| S. | Soldevilla-Canales* | Consultant, Co-national Director, Organic Banana project, Bolivia | Peru | 16-09-03 | Bolivia |
| C. | Staver | Senior Scientist, Coordinator Sustainable *Musa* production and utilization | USA | 01-01-04 | Montpellier |
| R. | Swennen | Honorary Research Fellow | Belgium | 01-12-95 | KUL, Belgium |
| J. | Tetang Tchinda | Regional Information Officer for Africa | Cameroon | 15-08-02 | Cameroon |
| I. | Van den Bergh | Associate Scientist, *Musa* Technology Transfer | Belgium | 01-10-97 | Philippines |
| I. | Van den Houwe | Officer in Charge ITC | Belgium | 01-02-92 | ITC, Belgium |
| L. | Vega | Programme Assistant | Costa Rica | 01-02-92 | Costa Rica |
| A. | Vézina | Science Writer and Public awareness specialist | Canada | 15-07-02 | Montpellier |
| T. | Vidal | Computer Service Assistant | France | 01-10-03 | Montpellier |
| A. | Vilarinhos* | Associate Scientist, Molecular biology | Brazil | 01-09-00 | Montpellier |
| S. | Voets | Administrative Assistant | Belgium | 01-01-93 | ITC, Belgium |

** left during the year.*

List indicates members of the INIBAP programme of IPGRI. In addition, staff within other programmes and departments of IPGRI contributed to the INIBAP programme during 2004.

## Acronyms and abbreviations

| | |
|---|---|
| ADRA | Adventist Development and Relief Agency, Tanzania |
| AFLP | Amplified Fragment Length Polymorphism |
| ARC | Austrian Research Centre, Austria |
| ARDI | Agriculture Research and Development Institute, Tanzania |
| ASARECA | Association for Strengthening Agricultural Research in Eastern and Central Africa |
| BAC | bacterial artificial chromosome |
| BAPNET | Banana Asia and Pacific Network |
| BARI | Bangladesh Agricultural Research Institute, Bangladesh |
| BARNESA | Banana Research Network for Eastern and Southern Africa |
| BBTV | banana bunchy top virus |
| BEL | BSV expressed locus |
| BLSD | black leaf streak disease |
| BPI | Bureau of Plant Industries, Philippines |
| BRIS | Banana Research Information System, INIBAP |
| BSV | banana streak virus |
| BSV-Gf | BSV-Gold finger |
| BSV-Im | BSV-Imove |
| BSV-Mys | BSV-Mysore |
| BSV-OI | BSV-Obino l'ewai |
| BTI | Boyce Thomson Institute for Plant Research, USA |
| CARBAP | Centre africain de recherches sur bananiers et plantains, Cameroon |
| CARDER | Centre d'action régionale pour le développement, Benin |
| CARDI | Cambodian Agricultural Research and Development Institute, Cambodia |
| CATAS | Chinese Academy of Tropical Agricultural Sciences, China |
| CATIE | Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica |
| cDNA | Complementary DNA |
| CENARGEN | Centro Nacional de Pesquisa de Recursos Geneticos y Biotecnologia, Brazil |
| CFC | Common Fund for Commodities, Netherlands |
| CGIAR | Consultative Group on International Agricultural Research |
| CIB-UNALMED | Corporación para Investigaciones Biológicas – Universidad Nacional de Colombia, Colombia |
| CIBE | Centro Investigaciones Biotecnológicas del Ecuador, Ecuador |
| CICY | Centro de Investigaciónes Científicas de Yucatán, Mexico |
| CIMMYT | Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico |
| CINVESTAV | Centro de Investigación y de Estudios Avanzados del IPN, Mexico |
| CIRAD | Centre de coopération internationale en recherche agronomique pour le développement, France |
| CNRA | Centre National de Recherche Agronomique, Côte d'Ivoire |
| CORAF | Conférence des Responsables de la Recherche Agronomique Africains |
| CORBANA | Corporación Bananera Nacional, Costa Rica |
| CORPOICA | Corporación Colombiana de Investigación Agropecuaria, Colombia |
| COS | Conserved orthologous set |
| CSIR | Council for Scientific and Industrial Research, Ghana |
| CTA | Technical Centre for Agriculture and Rural Cooperation ACP-EU, Netherlands |
| CvSU | Cavite State University, Philippines |
| DA-BAR | Department of Agriculture – Bureau of Agricultural Research, Philippines |
| DGDC | Directorate General for Development Cooperation, Belgium |
| DMMMSU | Don Mariano Marcos Memorial State University, Philippines |
| DNA | deoxyribonucleic acid |
| DPIF | Department of Primary Industries and Fisheries, Australia |
| DRC | Democratic Republic of Congo |
| EAHB | East African highland banana |
| EMBRAPA | Empresa Brasiliera de Pesquisa Agropecuaria, Brazil |
| ESPOL | Escuela Politécnica del Litoral, Ecuador |
| EST | expressed sequence tag |
| ETH | Eidgenössische Technische Hochschule Zürich, Switzerland |
| EU | European Union |
| FABI | Forestry and Agricultural Biotechnology Institute, South Africa |
| FADECO | Family Alliance for Development and Cooperation, Tanzania |
| FAO | Food and Agriculture Organization of the United Nations, Italy |
| FAO/IAEA | FAO International Atomic Energy Agency, Austria |
| FARA | Forum for Agricultural Research in Africa |
| FFTC | Food and Fertilizer Technology Center, Philippines |
| FHIA | Fundación Hondureña de Investigación Agrícola, Honduras |
| FONTAGRO | Fondo Regional de Tecnología Agropecuaria, USA |
| FUNDAGRO | Fundación para el Desarrollo Agropecuario, Ecuador |
| GCP | Generation Challenge Program |
| GDAAS | Guandong Academy of Agricultural Sciences, China |
| HORDI | Horticultural Research and Development Institute, Sri Lanka |
| IAEA | International Atomic Energy Agency, Austria |
| HRI | Horticultural Research Institute, Thailand |
| IBP | Instituto de Biotechnologia de las Plantas, Cuba |
| IBRD | International Bank for Reconstruction and Development, USA |
| ICA | Instituto Colombiano Agropecuario, Colombia |
| ICHORD | Indonesian Center for Horticulture Research and Development, Indonesia |
| IDIAF | Instituto Dominicano de Investigaciones Agropecuarias y Forestales, Dominican Republic |
| IDIAP | Instituto de Investigaciones Agropecuarias de Panamá, Panama |
| IDRC | International Development Research Centre, Canada |
| IEB | Institute for Experimental Botany, Czech Republic |
| IFAD | International Fund for Agricultural Development, Italy |
| IFPRI | International Food Policy Research Institute, USA |
| IFRURI | Indonesian Fruit Research Institute, Indonesia |
| IICA | Institut Interaméricain de Coopération pour l'Agriculture, Haiti |
| IIHR | Indian Institute of Horticultural Research, India |
| IITA | International Institute for Tropical Agriculture, Nigeria |
| IITA-ESARC | IITA- Eastern and Southern Africa Regional Centre, Uganda |
| ILAC | Institutional Learning and Change |
| IMTP | International *Musa* Testing Programme |
| INERA | Institut National pour l'Etude et la Recherche Agronomiques, Democratic Republic of Congo |
| INIA | Instituto Nacional de Investigacao Agronomica, Mozambique |
| INIA | Instituto Nacional de Investigaciones Agrícolas, Venezuela |
| INRAB | Institut national de recherché agricole du Bénin, Benin |
| IPB | Institute for Plant Breeding, Philippines |
| IPGRI | International Plant Genetic Resources Institute, Italy |
| IRAG | Institut de Recherche Agronomique en Guinée, Guinea |
| IRAP | Inter-retroelement amplified polymorphisms |
| ISPSC | Ilocos Sur Polytechnic State College, Philippines |
| ITC | INIBAP Transit Centre, Belgium |
| JIC | John Innes Centre, United Kingdom |
| KULeuven | Katholieke Universiteit Leuven, Belgium |
| MARDI | Malaysian Agricultural Research and Development Institute, Malaysia |
| MAS | Myanmar Agriculture Service, Myanmar |
| MGIS | *Musa* Germplasm Information System |
| MinSCAT | Mindoro State College for Agriculture and Technology, Philippines |
| MIPS/GSF | Munich Information Center for Protein Sequences/Forschungszentrum für Umwelt und Gesundheit, Germany |
| MTS | medium term storage |
| *MUSA*CO | *Musa* Research Network for West and Central Africa |
| *MUSA*LAC | Plantain and Banana Research and Development Network for Latin America and the Caribbean |
| *MUSA*LIT | INIBAP bibliographic database |
| NARI | National Agricultural Research Institute, Papua New Guinea |
| NARO | National Agricultural Research Organization, Uganda |
| NARS | national agricultural research systems |
| NIAS | National Institute of Agrobiological Sciences, Japan |
| NRCB | National Research Centre on Banana, India |
| NRMDC | National repository, multiplication and dissemination centre |
| NSF | National Science Foundation, United States of America |
| PAC | Pampanga Agricultural College, Philippines |
| PCARRD | Philippines Council for Agriculture Resources Research and Development, Philippines |
| PHP | hypertext Preprocessor |
| PIF | plants issus de fragments |
| PPRI | Plant Protection Research Institute, South Africa |
| PRI | Plant Research International, Netherlands |
| PRO*MUSA* | Global Programme for *Musa* Improvement |
| QDPI | Queensland Department of Primary Industries |
| QSC | Quirino State College, Philippines |
| QUT | Queensland University of Technology, Australia |
| RFLP | restriction fragment length polymorphism |
| RISBAP | Regional Information System for Banana and Plantain in Asia and the Pacific |
| RNA | ribonucleic acid |
| SACCAR | South African Centre for Cooperation in Agricultural Research, Botswana |
| SAGE | Serial analysis of gene expression |
| SARI | Southern Agricultural Research Institute, Ethiopia |
| SCAU | South China Agricultural University, China |
| SLPC | Southern Luzon Polytechnic College, Philippines |
| SPC | Secretariat of the Pacific Community, Fiji |
| SSH | suppression subtractive hybridization |
| SSR | simple sequence repeat |
| TARGET | Technology Applications for Rural Growth and Economic Transformation, USA |
| TAS | triple antibody sandwich |
| TBRI | Taiwan Banana Research Institute |
| T-DNA | transferred DNA |
| TIGR | The Institute for Genomic Research, USA |
| UCL | Université Catholique de Louvain, Belgium |
| UEM | University Eduardo Mondland, Mozambique |
| UK | United Kingdom |
| UM | University of Malaysia, Malaysia |
| UNAN-LEON | Universidad Nacional Autónoma de Nicaragua-León, Nicaragua |
| USA | United States of America |
| USAID | United States Agency for International Development, USA |
| VASI | Vietnam Agricultural Science Institute, Vietnam |
| VIMDESALT | Viceministerio de Desarrollo Alternativo, Bolivia |
| VVOB | Vlaamse Vereniging voor Ontwikkelingsamenwerking en Technische Bijstand, Belgium |
| WAU | Wageningen Universiteit, the Netherlands |
| WECARD | West and Central African Council for Agricultural Research and Development |
| WV Ghana | World Vision Ghana, Ghana |